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A Framework for Prioritizing Opportunities of Improvement in the Context of Business Excellence Model in Healthcare Organization

Alia Aldarmaki

A FRAMEWORK FOR PRIORITIZING OPPORTUNITIES OF IMPROVEMENT IN THE CONTEXT OF BUSINESS EXCELLENCE MODEL IN HEALTHCARE ORGANIZATION

by

ALIA HAMAD ALDARMAKI
B.S. Electrical Engineering, United Arab Emirates University, United Arab Emirates, 2011
M.S. Engineering Management, University of Central Florida, USA, 2014

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Major professor: Ahmad Elshennawy

ABSTRACT

In today's world, the healthcare sector is facing challenges to improve the efficiency and effectiveness of its operations. More and more improvement projects are being adopted to enhance healthcare services, making it more patient-centric, and enabling better cost control. Healthcare organizations strive to identify and carry out such improvement initiatives to sustain their businesses and gain competitive advantage. Seeking to reach a higher operational level of excellence, healthcare organizations utilize business excellence criteria to conduct assessment and identify organizational strengths and weaknesses. However, while such assessments routinely identify numerous areas for potential improvement, it is not feasible to conduct all improvement projects simultaneously due to limitations in time, capital, and personnel, as well as conflict with other organization's projects or strategic objectives. An effective prioritization and selection approach is valuable in that it can assist the organization to optimize its available resources and outcomes. This study attempts to enable such an approach by developing a framework to prioritize improvement opportunities in healthcare in the context of the business excellence model through the integration of the Fuzzy Delphi Method and Fuzzy Interface System.

To carry out the evaluation process, the framework consists of two phases. The first phase utilizes Fuzzy Delphi Method to identify the most significant factors that should be considered in healthcare for electing the improvement projects. The FDM is employed to handle the subjectivity of human assessment. The research identifies potential factors for evaluating projects, then utilizes FDM to capture expertise knowledge. The first round in FDM is intended to validate the identified list of factors from experts; which includes collecting additional factors

from experts that the literature might have overlooked. When an acceptable level of consensus has been reached, a second round is conducted to obtain experts' and other related stakeholders' opinions on the appropriate weight of each factor's importance. Finally, FDM analyses eliminate or retain the criteria to produce a final list of critical factors to select improvement projects.

The second phase in the framework attempts to prioritize improvement initiatives using the Hierarchical Fuzzy Interface System. The Fuzzy Interface System combines the experts' ratings for each improvement opportunity with respect to the factors deemed critical to compute the priority index. In the process of calculating the priority index, the framework allows the estimation of other intermediate indices including: social, financial impact, strategical, operational feasibility, and managerial indices. These indices bring an insight into the improvement opportunities with respect to each framework's dimensions. The framework allows for a reduction of the bias in the assessment by developing a knowledge based on the perspectives of multiple experts.

To

My beloved father and mother,

For their prayers and support, which made who I am.

To

My beloved kids, Maitha and Saeed,

For the happiness you bring to my life.

To

My husband, Ali Aldhaheri,

For his support, sacrifice, constant encouragement, and unconditional love

This effort is dedicated to you all

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LIST OF ABBREVIATIONS

AHP	Analytical Hierarchical Process
ANP	Analytic Network Process
ASQ	American Society for Quality
BEMs	Business Excellence Models
CFS	Critical Success Factors
CITC	Corrected Item Total Correlation
COG	Center of Gravity
DEMATEL	Decision Making Trial and Evaluation Laboratory
EFA	Exploratory Factor Analysis
EFQM	European Foundation for Quality Management
FDM	Fuzzy DELPHI Method
FIS	Fuzzy Interface System
FRBS	Fuzzy Rule Based System
FMEA	Failure Mode and Effect Analysis
HFS	Hierarchical Fuzzy System
JCI	Joint Commission International
KMO	Kaiser Meyer Olkin
LSS	Lean Six Sigma
LoS	Length of Stay
MADM	Multiple Attribute Decision Making

MAUT	Multi Attribute Utility Theory
MBNQA	Malcolm Baldrige National Quality Award
MCDM	Multiple Criteria Decision Making
MOCM	Multiple Objective Criteria Making
NIST	National Institute of Standards and Technology
NRM	Network Relation Map
OD	Outpatient Department
PAM	Process Activity Mapping
PCA	Principal Component Analysis
PDCA	Plan-Do-Check-Act
QFD	Qualify Function Deployment
RADAR	Approach, Deploy, Assess, and Refine
SAW	Simple Additive Weighting
SS	Six Sigma
SPSS	Statistical Packages Social Sciences
TQM	Total Quality Management
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
VIKOR	VlseKriterijumska Optimizacija I Kompromisno Resenje
WHO	World Health Organization

CHAPTER 1: INTRODUCTION

1.1 Overview

Competition in the twenty- first century obligates organizations to continuously improve performance and achieve excellence (Foster, Johnson, Nelson, & Batalden, 2007). The use of Business Excellence Models (BEMs) is one popular method to achieve excellence nowadays in a variety of sectors (Mohammad, Mann, Grigg, & Wagner, 2009). BEMs offer a set of dimensions and criteria to asset current performance and shed light on an organization's weaknesses (Foster et al., 2007). Specifically, the criteria pose questions to let the organization determine how they address situations, which yields to identifying its performance gaps.

The literature highlighted BEMs numerus benefits to any organization. According to Brown (2000), BEM criteria assist an organization to improve its performance and its end results. They also permit best practices sharing and benchmarking among different corporations and industries around the globe (Mann & Grigg, 2004). These criteria serve as a guideline to understand organization performance in order to cope with the stakeholders' requirements and achieve the targeted objectives (Flynn & Saladin, 2001). BEMs also create a common language, promoting easier communication across an organization (Stahr, 2001). Moreover, it facilitates long-term growth and organizational learning (Dutt, Biswas, Arora, & Kar, 2012; Escrig & De Menezes, 2015; Martin-Castilla, 2002).

In today's complex world, the healthcare sector is facing multi-factorial challenges and growing pressure to improve efficiency and effectiveness, be patient-centric, have more cost control, and improve public results. In 2014, a report by The National Health Expenditure

Accounts announced that U.S. healthcare occupied 17.5% of the Gross Domestic Product, equaling 3 trillion US dollars in total; with 5.3% growth and a cost of $9,523 per person (NHEA, 2014). Regardless of this enormous expenditure, most consumers still consider the service's delivery of healthcare and treatment is inefficient and not patient-friendly (Fleiszer, Semenic, Ritchie, Richer, & Denis, 2015; Herzlinger, 2006). Thus, the healthcare sector requires further novel initiatives to accelerate its transformation.

BEMs are widely accepted frameworks to enhance healthcare performance and effectiveness (Foster et al., 2007). There has been a noticeable growth in the adoption of BEMs in healthcare systems worldwide and applying for its awards. According to the National Institute of Standards and Technology (NIST), applicants for the Malcolm Baldrige National Quality Award (MBNQA) in healthcare have increased since the first introduction of healthcare specific version in 1999 (NIST, 2015). *Figure 1-1* illustrates the MBNQA healthcare applicants and award recipients from 1999-2015. Due to the high number of applicants, NIST in 2012 revised the eligibility rules to decrease the applicants' applications and limit the participation to high maturity organization only. Thus, since 2012 and onward total applicants number had been decreased. On the other side, award recipients are considered low comparing to total applicants. Healthcare sector recorded the maximum number of award recipients in 2011 by winning three awards.

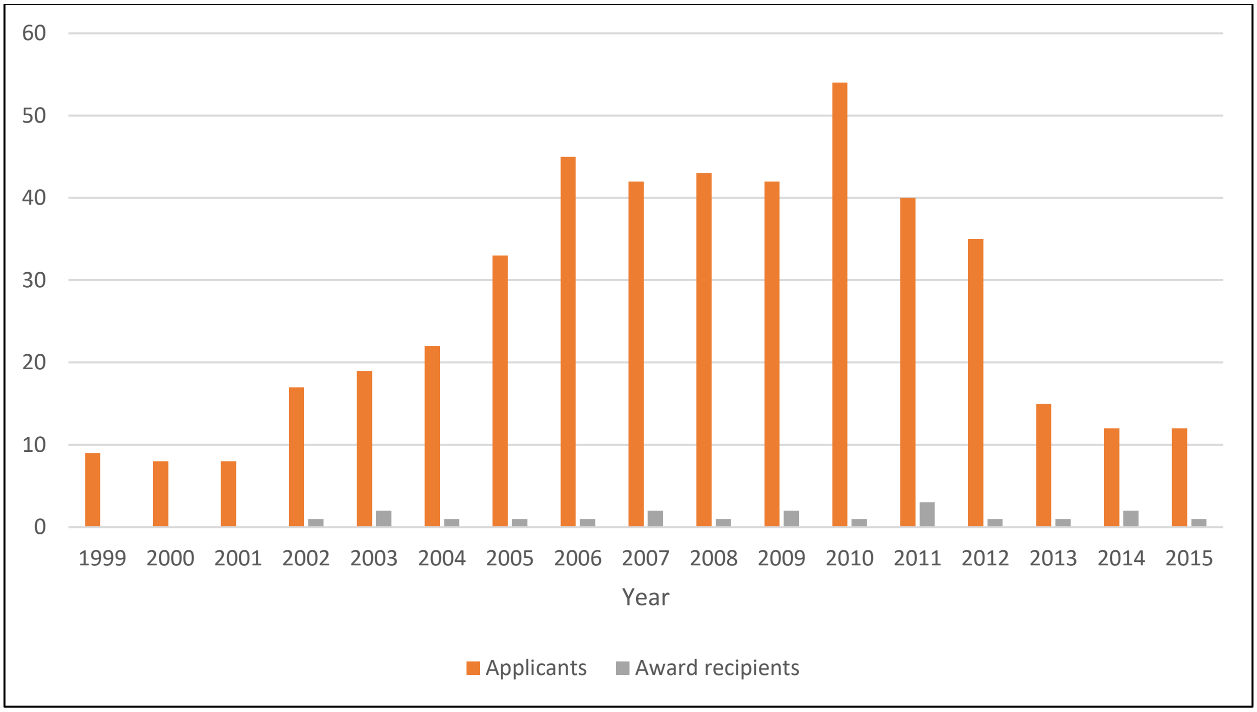


Figure 1-1:Malcolm Baldrige National Quality Award applicants and award recipients in healthcare (1999-2015)

Source: National Institute of Standards and Technology (NIST)

The MBNQA is not the only award which has experienced a growth in applicants; other business excellence awards like European Foundation for Quality Management (EFQM) Award has reported similar growth in the number of recognized healthcare organizations. Figure 1-2 demonstrates the number of recognized healthcare service organizations earning EFQM Awards from 2010-2016. The recognized organizations are not limited to European countries, but include organizations from the Russian Federation, Turkey, and Kazakhstan as well.

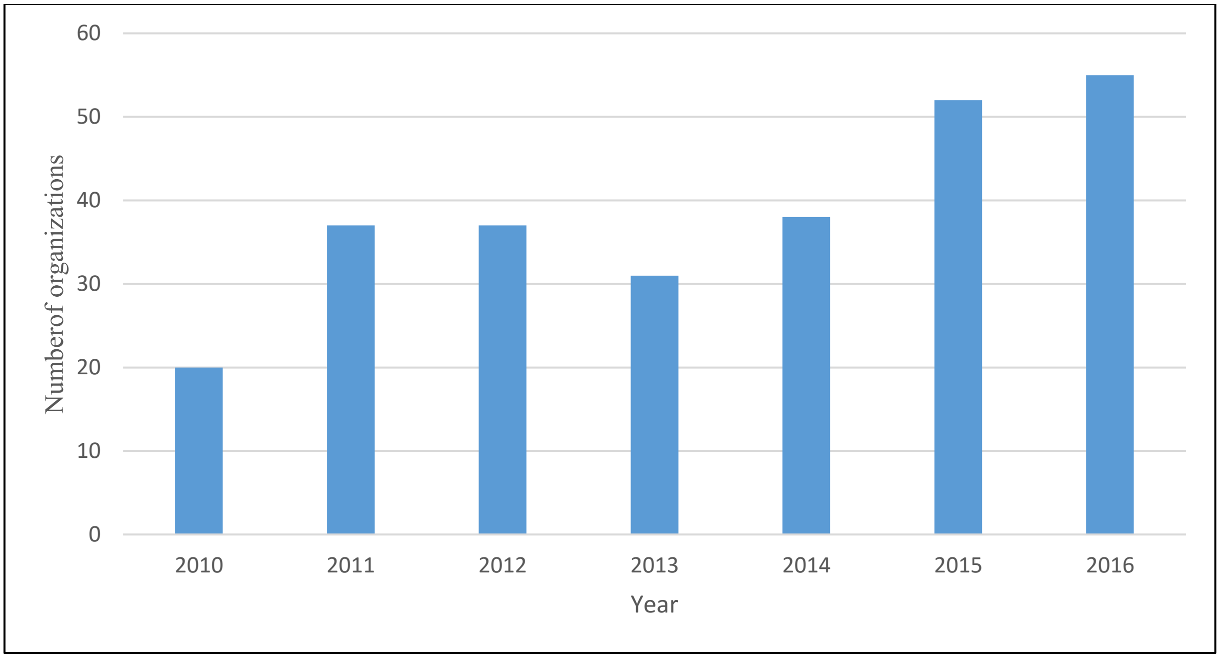


Figure 1-2: Recognized healthcare service organizations in EFQM (2010-2016)

Source: European Foundation for Quality Management recongnstion database

The EFQM developed a recognition scheme by creating milestones to emphasize progress and systematic improvements. The high level of recognition scheme includes three categories. The first category is the “Committed to Excellence” category, where EFQM ensures that an organization is moving in the right direction from the early stages of adopting EFQM. The second category is “Recognized for Excellence”. The organizations in this category applied for a peer-assessment by EFQM to provide insight into their current practices and pinpoint opportunities for improvement. Lastly, category three is the “EFQM Excellence Award.” Top-notch organizations holding a 5-star rating in the “Recognized for Excellence” category in the previous two years should demonstrate a competitive advantage over their peers and plan to maintain it in the future to achieve EFQM award. Figure 1-3 illustrates the number of organizations in the three categories of recognized healthcare service in EFQM from 2010 to

2016. It is evident from the figure that the number of the recognized healthcare organizations in each category has increased throughout the years. In 2015 there were healthcare organizations in the third category for the first time. This proves that healthcare communities have a growing interest in enhancing business excellence.

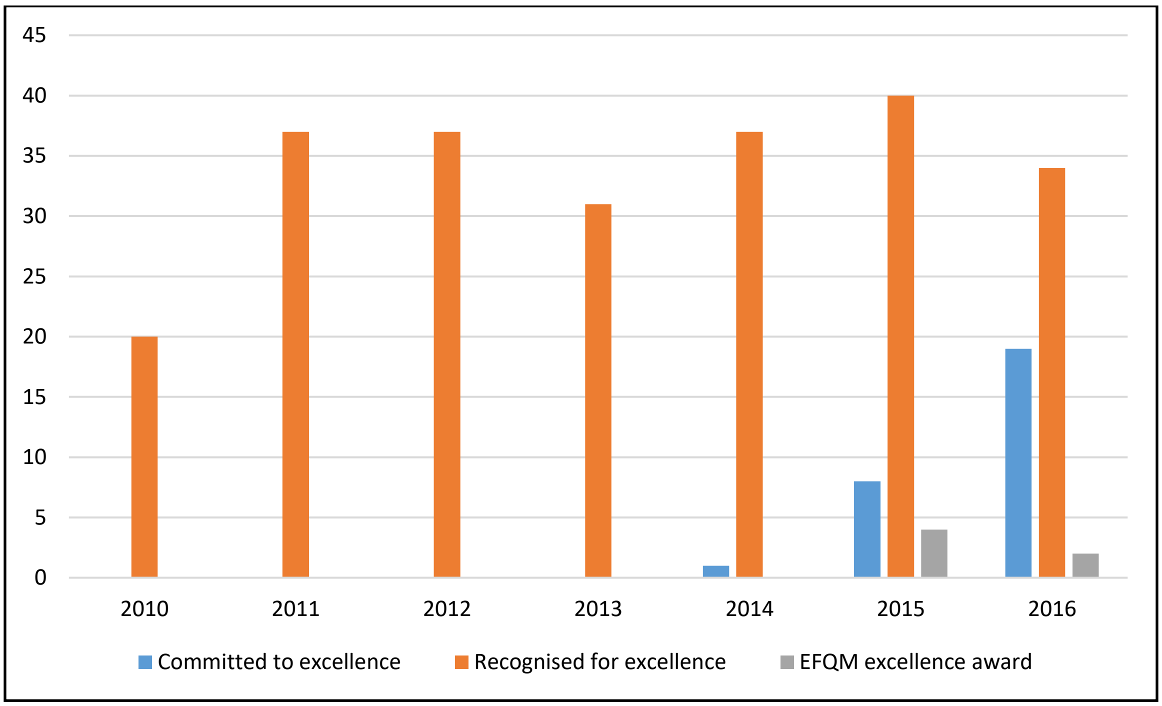


Figure 1-3: The recognized healthcare service categories in EFQM (2010-2016)

Source: European Foundation for Quality Management recongnstion database

The literature has interpreted that the growing interest in using a business excellence model is due to the tangible benefits that healthcare systems can gain from this adoption (Dehnavieh et al., 2012; Mundongo, Ditend, VanCaillie, & Malonga, 2014). In healthcare, BEMs have been shown to enhance patient satisfaction (Favaretti et al., 2015; Sanchez et al., 2006), clinical and non-clinical operations (Sanchez et al., 2006; Stahr, 2001; Vallejo et al., 2007), the work environment (Favaretti et al., 2015; Leigh, Douglas, Lee, & Douglas, 2005; Mundongo et al., 2014), healthcare societal impact (Stahr, 2001; Vallejo et al., 2007), and profits (NIST, 2015; Stahr, 2001). To experience all of the previous benefits, healthcare organizations should be selective in implementing improvement opportunities based on BEMs assessment and feedback. However, it is not feasible to conduct all improvement projects simultaneously due to limitations in time, capital, and personnel, as well as possible conflicts with other projects or the organization's objectives. An effective prioritization and project selection approach is vital to assist the organization in optimizing the available resources and outcomes.

BEMs have been criticized in the literature for the fact that they don't provide any mechanism by which to prioritize improvement initiatives (Dodangeh et al., 2011; Dodangeh et al., 2012; Kirkham, Garza-Reyes, Kumar, & Antony, 2014; Nazemi, 2010). At the same time BEM panels believe that this is outside the scope of the assessment and it is the responsibility of the organization to make such prioritization (Baldridge feedback report, 2014; EFQM feedback report, 2014). Hence, there is a need for a quantitative tool beyond BEMs to examine different aspects of judgment and select the most effective improvement decision.

1.2 Research Problem statement

As illustrated in the previous section, BEM utilization is increasing each year worldwide, especially in the healthcare industry. Nevertheless, selecting the most effective improvement initiatives from a pool of improvement initiatives derived from a BEM assessment is a challenge due to the limited resources, time, and budget in the healthcare sector.

Even though there have been a few research efforts to develop frameworks to select the most relevant improvement opportunities in the context of BEMs in various industries, the literature reveals only one such existing framework developed in a healthcare setting. Moreover, it has been noted that those frameworks mainly rely on managers and focus group perspectives to inform decision making, neglecting other stakeholders' perspectives. The contribution to improvements in healthcare made by management groups cannot be overlooked, but their interests and priorities do not necessarily coincide with those of other stakeholders like patients, physicians, and nurses. In any enterprise, neglecting stakeholders' preference in decision-making leads to massive failure as a result of undesirable outcomes (Müller & Thoring, 2012), and the result of such a situation in the healthcare system is not an exception. Therefore, it is important to prioritize improvement initiatives in healthcare based on the input of affected parties in addition to healthcare providers. In addition to a lack of stakeholder involvement, the precision of the developed frameworks has been a concern, because it does not account for the uncertainty and the subjective nature of human judgment.

Thus, a need has been identified to design a better quantitative tool to optimize the selection of improvement initiatives in the context of BEMs in the healthcare system which considers the different stakeholders' preference and the subjective nature of human judgment using customized healthcare criteria.

1.3 Research Objectives

Business excellence models are widely utilized in healthcare system around the world. In order to maximize the benefits from the evaluation outcomes, proper action plans should be conducted to carry out improvement projects. However, prior to developing an action plan, only relevant and feasible improvement opportunities need to be selected. To prioritize these opportunities, a novel framework should be developed to facilitate the decision-making process in the healthcare system.

The main objective of this research is to develop a framework to allow decision makers in a healthcare system to prioritize and select the most effective improvement initiatives in the context of BEMs. The framework will capture different stakeholders' preferences, reveal subjective judgments, and allow model scalability. Also, it will permit relevant criteria selection to take into consideration the distinct characteristics of the studied healthcare system and the impact of the region's requirements. Additionally, the research will assess the reliability of the developed framework and validate the usability of it. This will be accomplished by conducting a case study that involves collecting and analyzing data from designated hospitals.

1.4 Research Questions

This research aims to answer the following main question:

What is an appropriate quantitative instrument that can prioritize the improvement opportunities in the context of business excellence in the healthcare system, which will identify healthcare system indicators for prioritization, deal with the different stakeholders' perspectives, and take into consideration uncertainty of human judgment?

1.5 Research Contribution

This research will contribute to the existing body of knowledge by developing a framework for prioritizing and selecting the most effective improvement initiatives in the context of BEMs in a healthcare system. The purpose of the framework is to involve different stakeholders in healthcare in decision making while accounting for various aspects of the system and decision-making process that might assist healthcare system boards to make a robust and more effective decision. The proposed framework is unique in various ways. First, it proposes using a hybrid method of Fuzzy DELPHI and Fuzzy Interface System. The Fuzzy DELPHI has the ability to capture participants' perspectives, while Fuzzy Interface System prioritizes alternatives to select the optimal ones. Second, the developed framework allows for not only prioritizing of improvement initiatives, but also consideration of multiple stakeholders, thereby overcoming the problem of improvement selection based on management group preferences only. The framework's results can be used by the leading stakeholders to ultimately make optimized decisions. In addition, this research provides insight into the factors related to prioritizing healthcare improvements, which can serve as valuable input for future studies. The end result may also be utilized by other researchers to measure the effectiveness of prioritizing and implementing the improvement initiatives on the overall results of applying BEMs in healthcare settings.

1.6 Organization of the Dissertation

The rest of this document is organized as follows. Chapter two provides a detailed review of the relevant literature to clarify the different areas associated with the research objectives.

This chapter first presents business excellence concepts and reviews the most popular models around the globe. Then it explores project selection and prioritization methods and elaborates in-depth on the existing academic work that has been done to select and prioritize improvement initiatives in the context of business excellence. Chapter two also investigates current trends, contemporary challenges, and the process of decision making in the healthcare system. The last section of chapter two synthesizes the previous information in performing a gap analysis to reveal a literature gap.

Chapter three describes the research methodology implemented in this research. It presents a detailed plan, from problem definitions to results and recommendations. This chapter introduces a preliminary framework to optimize prioritization and selection of improvement opportunities of a business excellence model in healthcare. chapter Four describes the constructed framework and the related conceptual and technical aspects. The first part of the chapter includes the FDM algorithm to identify the key evaluation factors, the methods of eliciting experts and stakeholder, and the procedure of indicators assessment. The second part of this chapter expands on the process of building the FIS scheme and describes its architecture in detail. Chapter five demonstrates the process of implementing the proposed framework and analyzes the obtained results. Additionally, reliability and initial and invalidation tests are discussed. Finally, chapter Six concludes the research by highlighting the major findings and discussing the research contribution. Research limitation and recommendation for future research are discussed.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Business excellence for more than a decade has provided a set of criteria for different organizations in a variety of industries to conduct assessment and identify areas needing improvement. In the healthcare system, business excellence is widely accepted as a rubout framework for evaluation and design (Foster et al., 2007). It plays a role in allowing an organization to gain a competitive advantage among other competitors. Healthcare systems are currently experiencing radical changes, an accelerating rate of transformation, and an uncertain future. Simultaneously, they are facing various challenges such as limited resources, increasing operational costs, a high demand for services and pressure to meet external requirements from government, health authority, and insurance companies (Hochenedel & Kleiner, 2016). Therefore, healthcare systems need to adopt an agile approach to appropriately select the most effective and efficient improvement initiatives in the context of business excellence.

The objective of this chapter is to examine the existing and the diverse academic studies that have been done in this area to provide an overview of the topic and offer insight into creating a novel work. To achieve these objectives this chapter first provides an overview of Total Quality Management (TQM): its definition, its promising benefits, successful factors in TQM implementation and the current shift to business excellence. Then it reviews the relevant literature on business excellence models. Moreover, the review includes projects' prioritization, definition, impact and models available to prioritize improvement. This chapter goes on to discuss in detail the business excellence models available to prioritize improvement opportunities to assess their applicability, reliability, and validity. In addition, the chapter also describes aspects related to the healthcare setting, quality initiatives in healthcare, and the utilization of the business model in healthcare. Finally, chapter two provides a background on the tools used in the developed framework such as the Fuzzy Delphi, fuzzy logic system, and their applications in the literature.

2.2 Total Quality Management

The seeds of Total Quality Management (TQM) were derived by American quality gurus like Deming, Juran, and Feigenbaum. Its principles revolted Japan economics to be one of the best global economies after World War II (Evans & Lindsay, 2005; Imai, 1986). TQM allows firms to reduce the defect and error rate, reduce waste, improve productivity and sales, improve market position including profit and market share, improve the supply chain and increase workforce and customer satisfaction (Brah, Tee, & Rao, 2002; Mashal & Ahmed, 2015; Mellat-Parast, 2013) Firms in the USA and UK began to take serious notice of TQM during the 1980s and 1990s (Powell, 1995; Psychogios & Wilkinson, 2007). The pressure from international competition and the increase in quality awareness among customers facilitated a substantial popularity of TQM (Willborn & Cheng, 1994).

The literature defines TQM as a comprehensive philosophy to continuously enhance business performance through a set of practices and the participation of the entire organization (Claver-Cortes, Pereira-Moliner, Tari, & Molina-Azorin, 2008; Mellat-Parast, 2013; Powell, 1995; Wali, Deshmukh, & Gupta, 2003). Dean and Bowen (1994) argue that most of what had been written about TQM to that point explicitly or implicitly evolved around three main principles: customer focus, continuous improvement and teamwork.

There is an enormous amount of literature present on TQM's application in various regions and industries. For example, Durlabhji and Fusilier (1999) proved that TQM is not restricted to a manufacturing setting. This study reviewed the results of applying TQM in academia, particularly among business school administrators and faculty. They report a high reduction in application processing time and the time needed to hand in grades as a result of TQM adoption. Al-Marsumi (2007) investigated the impact of TQM application in five hospitals in Jordan. Despite the variation in each hospitals' application, the results indicated a direct and positive correlation between the overall application and the chosen performance indicators. Siddiqui and Rahman (2007) evaluated the role of TQM in Information Systems (Bernardino et al.). Through the analysis of questionnaire-based survey data, the scholars were able to quantify top management's support for implementing TQM, the relation between TQM and IS, and realize TQMs benefits to IS. The researchers believed that the results might facilitate introducing TQM to IS firms to enhance end-product quality. In Hong Kong, Lau, Tang, and Li (2015) studied the level of TQM application by construction contractors. The study illustrated a high level of TQM's principles adoption. However, the result suggested that contractors should focus on two major principles, organizational learning and supplier management, to sustain long-term business.

Although many studies have demonstrated the potential of TQM to improve outcomes, several studies have also reported that TQM may also fail to produce the targeted benefits and only slightly improve the productivity by 20-30% (Eskildson, 1994; Schonberger, 1992; Tata & Prasad, 1998). Brown (1993) and Bak (1992) reported a failure rate of 70-80% for TQM program. These unsatisfying results have motivated several scholars to study TQM and its Critical Success Factors (CSF). Hietschold, Reinhardt, and Gurtner (2014) in their analysis of 145 studies classified CSFs into eleven dimensions associated with successful TQM implementation, listed below.

- HRM/Recognition/ Teamwork
- Top management commitment and leadership
- Process management
- Customer focus and satisfaction
- Supplier partnership
- Training and learning
- Information/ analysis/ data
- Strategic quality planning
- Culture and communication
- Benchmarking
- Social and environmental responsibility

Despite all of the researches of TQM adoption and evidence of its benefits, there is an ongoing debate among scholars about the current existence of TQM and the question is raising if TQM did fade during the quality movement? Bernardino et al. (2016) and Su Mi (2011) believed that TQM lost it attractiveness in the early 2000s and the current evidence indicates that organizations began to substitute for it with the business excellence approach, even though both approaches have common characteristics and the business excellence model is based on TQM's framework. In fact, Dotun (2001) argued that the reason behind TQM's fade in popularity was the wide acceptance of BEMs. However, scholars like (Dale, 2000) claimed that business excellence is only a change in terminology. Kiauta (2012) argued that the new terminology is an expansion of quality, moving beyond the understanding of quality as related to product and services to quality as a way of maximizing business effectiveness to meet or exceed customer value. He defined business excellence as achieving the highest level of quality.

2.3 Business Excellence

The literature reveals two approaches on the adoption of business excellence models in an organization. The first one performs as a tool to quantify current performance and achieved results (Jayamaha, Grigg, & Mann, 2009). The second acts as improvement guideline to achieve stakeholder targeted results (Flynn & Saladin, 2001). There is a significant amount of literature that establishes a link between investing in excellence/quality programs and improving the organization's performance (Dow, Samson, & Ford, 1999; Easton & Jarrell, 1998; Martínez-Costa & Jimenez-Jimenez, 2008).

Several developed and developing countries have established National Quality Awards, or business performance excellence awards based on BEMs (Dotun, 2001) to effectively promote excellence and improve quality dimensions awareness (Anil & Balvir, 2007; Vassilios, Sophia, & Constantine, 2007). By adopting business excellence models, various awards participants stated a noticeable improvement in customer satisfaction, employee engagement, supplier relations, market share, revenue, and processes (Anil & Balvir, 2007). Winners get an enormous reputation and outperform other non-winning organizations (Boulter, Bendell, & Dahlgaard, 2013).The impact of the awards extended far beyond the award's recipients or participants only

(Flynn & Saladin, 2001). The awards impose knowledge and sharing best practices to promote self-assessment, benchmarking, and re-shape top management approaches for participants or non-participants (Mann & Grigg, 2004). Nevertheless, winning the award is not the end solution for the organization's issues or an evidence of perfection (Anil & Balvir, 2007; Talwar, 2011). Accordingly, the literature argues that adopting a business excellence model does not assure long-term success (Evans, Ford, Masterson, & Hertz, 2012; Fisher, Dauterive, & Barfield, 2001).

In 2011, Talwar (2011) identified hundreds of excellence awards used by countries around the globe, and the number has grown even more since that time. However, the Deming Prize in Japan, the Malcolm Baldrige National Quality Award (MBNQA) in United States, and the European Foundation for Quality Management (EFQM) Excellence Award in Europe are the most prominent, and they are the reference for various awards (Anil & Balvir, 2007; Boulter et al., 2013; Talwar, 2011). According to Lee and Lee (2013), 42.1% of quality awards in the world are based on the EFQM model, 25.2 % are using the MBNQA model and 7.5% are based on the Deming Prize, while the other 25.2% are using other quality models.

Each award has its own unique system and culture, but all articulate TQM principles (Bou-Llusar, Escrig-Tena, Roca-Puig, & Beltrán-Martín, 2009; Dotun, 2001; A Ghobadian & H. S. Woo, 1996; Abby Ghobadian & Hong Seng Woo, 1996). In general, applying for any award involves extensive assessment process of records examination, top management/employee interviews, and site visits (Mann & Grigg, 2004). Independent assessors execute the process by evaluating the organization's performance against the BEMs categories using scoring guidelines (Jayamaha et al., 2009).

2.3.1 European Foundation for Quality Management (EFQM)

The EFQM was established in 1988 to promote quality standards in European companies and share knowledge and best practices. In Brussels, Fourteen European multinational companies were involved at that time: NV Philips' Gloeilampenfabrieken; Ing. C. Olivetti & C. SpA; Robert Bosch GmbH; Volkswagen AG; British Telecommunications plc; Bull SA; Ciba-Geigy AG; Avions Marcel Dessault-Breguet Aviation; Regie Nationale des Usines Renault; AB Electrolux, Fiat Auto SpA; Koninklijke Luchtvaart Maatschappji N.V.; Nestle´ SA; and Gebr. Sulzer AG (Conti, 2007; Vassilios et al., 2007). It is a nonprofit, membership-based organization and (Lee & Lee, 2013). EFQM developed the EFQM model to introduce self-assessment principles. The first European Quality Award Program was launched in 1992 (Conti, 2007; Moeller & Sonntag, 2001).

The lietatures demostrates several advantages of EFQM adoption. For example, Dutt et al. (2012) examined the usage of the EFQM model in an Indian company and discussed four different ways to utilize the model. First, the model supports developing realistic and measurable goals. Second, it enables the organization to understand their business systematically. Third, it allows the organization to measure its performance. Finally, successful application can lead to winning the EFQM award. Mann and Grigg (2004) studied EFQM as way of benchmarking and sharing best practices. In addition, the model creates a common language and enables communication across the organization (Stahr, 2001). Overall, it seems that adopting the EFQM facilitates continous improvement and secure long-term growth through identifying area of improvements (Dutt et al., 2012; Escrig & De Menezes, 2015; Martin-Castilla, 2002).

The EFQM Excellence Model, depicted in *Figure 2-1*, includes nine criteria. The first five criteria -- leadership, policy and strategy, people, partnerships and resources, and processes -- are called enablers. Examining the enablers allows investigation of the current organization's performance. The other four criteria are related to results in the areas of customers, society, people and business. The results criteria measure the organization's outcomes. The upper arrows in the model demonstrate how the enablers generate the results; thus good enablers implementation yields good results. The lower arrow emphasizes how feedback can improve the enablers through innovation and learning. The nine criteria are divided into 32 sub-criteria (see in appendix A). They are weighted based on their importance. Below is further elaboration about each of the EFQM main criteria.

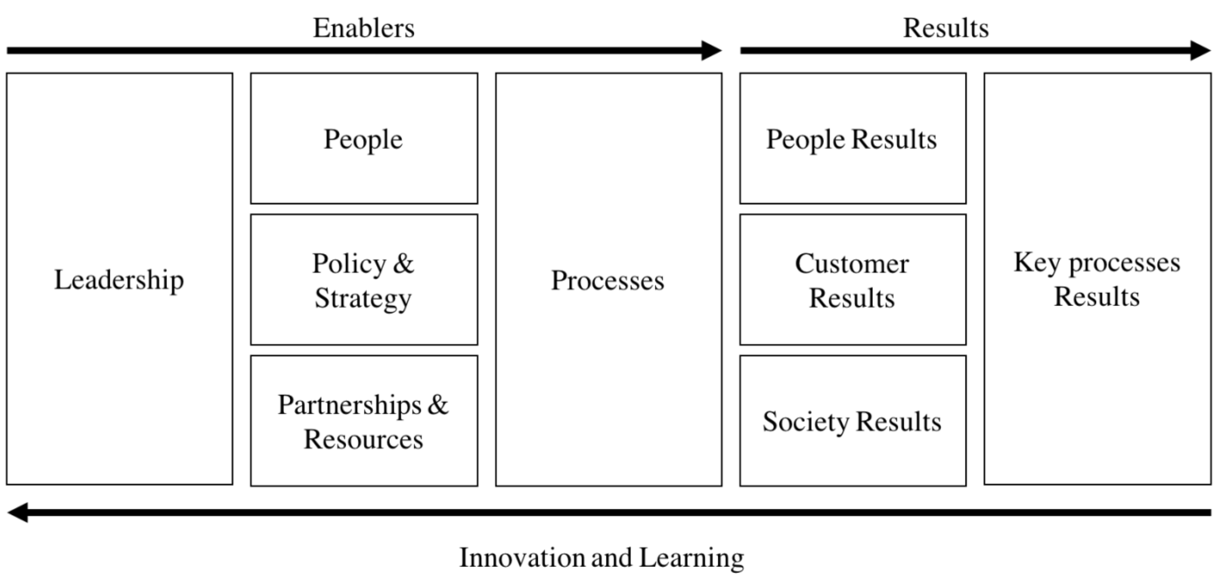


Figure 2-1: EFQM model

Adapted from: EFQM, 2012

Leadership

Excellent organizations have a visionary leadership and persist in developing and achieving the organization's mission and vision (Dodangeh et al., 2011). They represent the organization's values and ethics and show visible support to quality at all levels (Dean Jr & Bowen, 1994). Excellent leaders are involved in cultural change and invest in workforces and resources to support development (Ahire, Golhar, & Waller, 1996). They are flexible and enable sustainable organizational success and achievement of long-term targets through their actions (EFQM, 2012; Savić, Djordjević, Nikolić, Mihajlović, & Živkovic, 2014)

People

Managing the workforce is the cornerstone of a successful organization (Ahmad & Schroeder, 2002). Thus, an excellent organization is able to manage and develop the individual or team-based capabilities of its workforce. It supports fairness and motivates achieving organizational and personal goals simultaneously (EFQM, 2012; Savić et al., 2014). Excellent organizations create a positive environment by utilizing suitable workforce selection, a bidirectional communication system (Zink & Schmidt, 1995), reward and recognition (Dodangeh et al., 2011), training and acquiring new skills (OsseoAsare & Longbottom, 2002).

Policy and strategy

Excellent organizations enact practical policies and strategies. Excellent organizations deploy and apply processes, policies, goals, and plans to execute strategy. They develop a stakeholder-oriented strategy to fulfill their vision and mission (EFQM, 2012). Ravichandran and Rai (1999) emphasize the importance of integrating quality policies and strategies into an organization's policies and strategies.

Partnership and resources

Excellent organizations effectively support operations, policies, and strategies through planning and leveraging internal resources, suppliers, and partnerships since appropriate partnership management promotes process governance (Safari, Abdollahi, & Ghasemi, 2012). The criterion includes assessing the organization's current and future needs, social impact, and environmental impact (EFQM, 2012).

Process

OsseoAsare and Longbottom (2002) defined key processes as ones with a significant influence on the organization's results. Excellent organizations raise customer and stakeholder satisfaction through efficient planning, management, and improvements in their processes, services, or products (EFQM, 2012).

Customer results

According to Calvo-Mora, Leal, and Roldán (2005), achieving better customer satisfaction yields an improvement in the EFQM final result. A service or product's excellence is mainly determined by customers' perceptions. Thus, an excellent organization works to achieve or exceed customer expectations (EFQM, 2012).

People results

Logically, satisfied workers perform better in their jobs (Calvo-Mora et al., 2005). Therefore, with respect to their workforces, excellent organizations periodically measure results in areas such as occupational satisfaction, responsibility ratio, absence rate, and occupational accidents (Safari et al., 2012; Savić et al., 2014) and work to improve or sustain the measured values (EFQM, 2012).

Society results

The EFQM measures organizational contributions to the local and national communities (Savić et al., 2014), because excellent organizations actively participate in social events. They accomplish and maintain excellent results in this category (EFQM, 2012)

Business Results

The main purpose of establishing organizations is to generate outcomes, financial and non-financial. Excellent organizations comprehensively utilize indicators to develop a solid understanding of their businesses to predict and improve their key outcomes. Excellent organizations also achieve or exceed their stakeholders' expectations sustainably (EFQM, 2012)

2.3.1.1 RADAR Logic

RADAR logic is the heart of EFQM model (EFQM, 2012). It is a simple and dynamic management tool that introduces a structured approach to assess organizational performance. The EFQM model utilizes RADAR logic to facilitate the self-assessment process. Using RADAR logic with EFQM's nine criteria and sub-criteria requires an intensive and practical learning (Persaud, 2002).

RADAR stands for Results, Approach, Deploy, Assess, and Refine. The RADAR logic cycle is illustrated in Figure.2-2. In an ideal setting, the organization will:

- Determine achievable and realistic results in connection with the organization strategy
- Plan and develop approaches to accomplish the targeted result. The approaches are clear and well-defined, and they integrate shareholder requirements.

- Deploy structured approaches to ensure efficient implementation
- Monitor and analyze current actions to assess and refine the implemented approaches to enhance practices (EFQM, 2012).

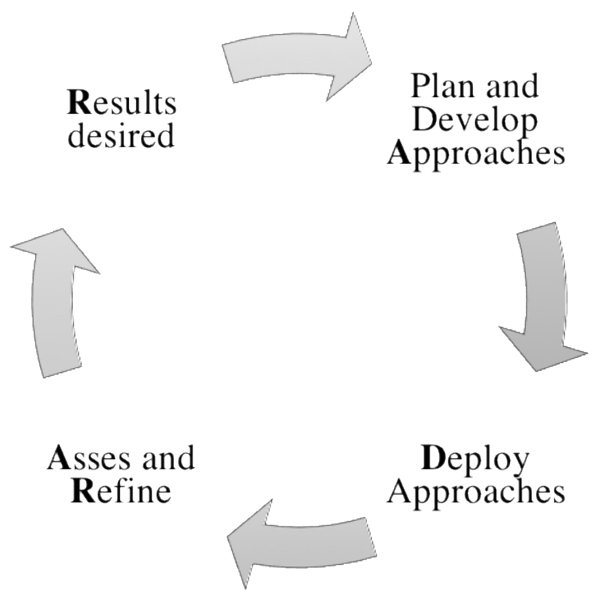


Figure.2-2: RADAR logic cycle

Adapted from: EFQM, 2012

RADAR logic is a modified version of the Deming cycle, or Plan-Do-Check-Act (PDCA) (Calvo-Mora, Picón, Ruiz, & Cauzo, 2014; Nabitz, Klazinga, & Walburg, 2000). It differs from PDCA in that results and goals are determined before planning and selecting the appropriate approach (Calvo-Mora et al., 2014). RADAR is employed to assess each sub-criterion from 0% to 100% on a five-point scale.

RADAR logic is a crucial component of EFQM excellence methodology. It provides a systematic approach to examining the organization's performance (Sokovic, Pavletic, & Pipan, 2010). Most of the literature elaborates on using RADAR as a self-assessment tool within the

EFQM model. Favaretti et al. (2015) evaluated the merit of adopting the EFQM as a self-assessment tool in a large healthcare system in Italy. This study showed there was a significant gain in the organization's excellence between 2001 and 2008, where the organization scored 290 out of 1000 in 2001 and improved to 610 in 2008. A similar study of a German healthcare organization described RADAR logic being used as an approach to quantify the organization's outcomes and level of success. The study showed that RADAR logic helped them to gain a competitive advantage (Moeller & Sonntag, 2001).

RADAR as a self-assessment tool is not restricted to use on the macro level, such as in a healthcare system or hospital. It can also be utilized at a micro level, such as in a department or program. Ana I Marques et al. (2011) adopted EFQM self-assessment for use in an elderly physical activity program. The program assessment helped the organization to understand the business, improve services, and ultimately reflect on total hospital performance.

RADAR logic supports the EFQM award scoring technique and various assessment schemes (Sokovic et al., 2010). It is a common measuring scheme across various industries and numerous countries worldwide; this allows for easy comparison of current practices with excellent organization practices and benchmarking (Stahr, 2001).

2.3.2 MBNQA model

The MBNQA was launched in 1987 by the US government to promote quality awareness, improve organizational performance, recognize organizations with top practices, and share best practices strategies and benefits (Anil & Balvir, 2007; Lee, Zuckweiler, & Trimi, 2006; Talwar, 2011). NIST manages the MBNQA with the assistance of the American Society for Quality (Velasquez & Hester) (Islam, 2007; Velasquez & Hester). According to MBNQA, quality is a customer-driven approach; thus it emphasizes establishing customer satisfaction as a way to achieve excellence (Talwar, 2011).

Since the MBNQA was established, its criteria have been revised at various times to match contemporary concepts of quality and adopt to the shift in business to a global level (Lee & Lee, 2013). Due to manufacturing competition between the U.S. and Japan in the 80s, the early criteria focused on quality engineering concepts like quality assurance standards, rework, and reduction of scrap. However, Lee et al. (2006) stated that those concepts had disappeared by 1997, with the criteria shifting to reflect more strategic approaches. Recent MBNQA consists of seven categories (Figure *2*-*3*): leadership, strategic planning, customer focus, measurement, analysis, knowledge management, workforce focus, operations focus, and results. The seven categories are weighted differently based on their relative importance and divided into 17 criteria items and areas to address (Sun, 2011) (seen in Appendix A). The organizational profile at the top of the figure is not a part of the evaluation process, but it sets the organizational context. In general, the framework emphasizes integration of the different categories. The horizontal arrow in the center illustrates the linkage between (leadership, strategic planning, customer focus) and (workforce focus, operations focus, results) while the vertical arrow represents the information sharing between the key processes and the system's foundation (MBNQA, 2015).

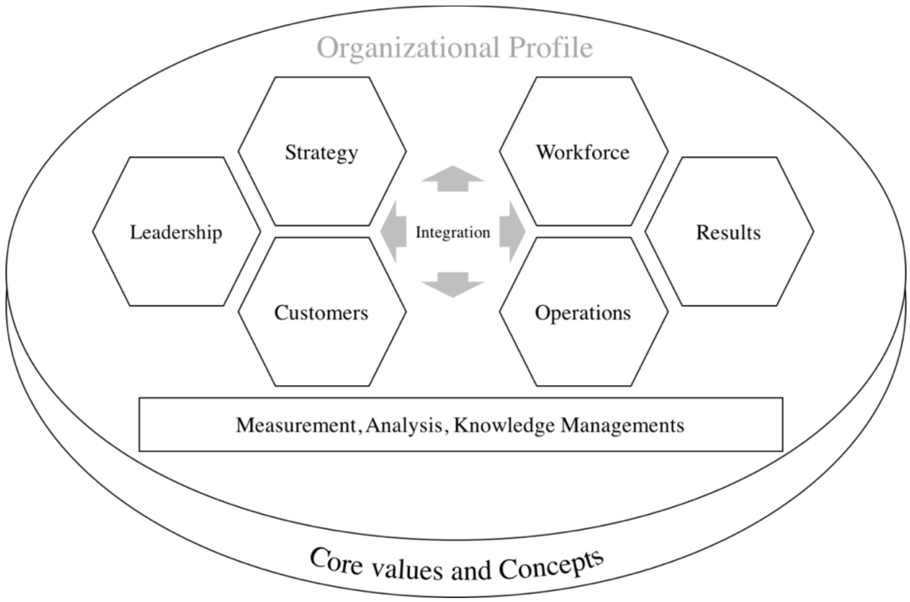


Figure 2-3: MBNQA framework

Adapted from: MBNQA, 2015

2.3.3 Comparison of EFQM and MBNQA

In 1992, EFQM established the EFQM model to promote quality in European companies, enhance their position, and close the quality gap between organizations in Europe and United States/Japan. EFQM follows the logic of the MBNQA model (Conti, 2007; Lee & Lee, 2013). Both models grew out of Total Quality Management (TQM) philosophy, and they share the same core elements (Al-Tabbaa, Gadd, & Ankrah, 2013; Bou-Llusar et al., 2009). The majority of the literature clusters both models into one category to compare them with other quality initiatives, such as ISO 9000 (Dodangeh et al., 2012; Dror, 2008; Vaxevanidis, Krivokapic , Stefanatos, Dasic, & Petropoulos 2006). Despite the common objectives and similar utilization of EFQM and MBNQA, there are still considerable differences between them.

The EFQM and the MBNQA models both utilize a 1000-point scale, yet they have different criteria, sub-criteria, and weights (Oger & Platt, 2002). The EFQM has nine criteria associated with 32 sub-criteria in comparison to the seven criteria and 19 sub-criteria of the MBNQA. Table 2-1 compares the models’ criteria and the associated weights.

Table 2-1:EFQM vs. MBNQA criteria

EFQM criteria	EFQM criteria weight	MBNQA criteria	MBNQA criteria weight
Leadership	100	Leadership	120
Policy and strategy	80	Strategic and planning	85
People	90	Customer and Market Focus	85
Partnership and resources	90	Measurement, analysis and	90
Processes	140	knowledge management	85
Customer results	200	HR focus	85
People results	90	Process management	450
Society results	60	Results	
Business results	150		

Oger and Platt (2002) attempt to clarify the weight differences between the two models by classifying the criteria into three categories: results, strategic enablers, and tactic enablers. Strategic enablers include leadership and policy, whereas tactic enablers include, people, resources, and processes. Strategic enablers have more weight in MBNQA, while tactic enablers have more weight in EFQM. Based on this observation, the scholars claim that MBNQA emphasizes planning and management while the EFQM emphasizes execution.

The literature credits the heavier weight on customer results, people results and society results in the EFQM model to the extensive workplace, social, and environmental regulation in Europe. The MBNQA, on the other hand, is credited with emphasizing business results as a result of American companies' interest in financial results (Lee et al., 2006; Oger & Platt, 2002).

Another major difference between the two models is the assessment tool or scoring system used. The EFQM utilizes RADAR logic (Results, Approach, Deployment, Assessment, and Refine) to evaluate each sub-criteria (Moeller & Sonntag, 2001). The last four steps of RADAR are associated with measuring the enablers (Savić et al., 2014). The MBNQA uses two evaluation dimensions in the scoring system: first, the ADLI (Approach, Deployment, Learning, and Integration) to evaluate processes from category one to six, and the LeTCI (Levels, Trends, Comparisons, and Integration) to assess category seven only (MBNQA, 2015)

2.4 Project prioritization and selection

Organizations strive to identify and carry out improvement initiatives to gain or sustain a competitive advantage (Kirkham et al., 2014). Seeking to reach a higher operational excellence level, they routinely identify numerous areas for potential improvement. (Pyzdek, 2014). Selecting one project or portfolio of projects to focus on out of a pool of alternatives is a difficult task (Jung & Sang-Gyu, 2007), because there are various limitations and uncertainties associated with each project in terms of time, capital, and personnel, as well as possible conflicts with other projects or the organization's objectives. Thus, it is not feasible to conduct all improvement initiatives simultaneously (Marriott, Garza-Reyes, Soriano-Meier, & Antony, 2013).

According to Pyzdek (2014), prioritization is a method of arranging and dealing with projects according to their importance. Jung and Sang-Gyu (2007); (F. K. Wang, C. H. Hsu, & G. H. Tzeng, 2014) and F. K. Wang et al. (2014) described project selection as a process of selecting the optimum alternative using the most vital criteria. Different scholars emphasize that appropriate project prioritization and selection is likely to increase the success rate of operations improvement projects (Abbasianjahromi & Rajaie, 2013; Water & Vries, 2006). In fact, some scholars even argue that it is a key factor for improvement program success (Hsieh, Huang, & Wang, 2012; Marriott et al., 2013).

Effective prioritization and selection assist an organization to find the balance between costs, risks, and potential benefits while constructing an investment portfolio (Abbasianjahromi & Rajaie, 2013; Phillips & Bana e Costa, 2007). They also ensure correct allocation and optimization of available resources (LePrevost & Mazur, 2005; Marriott et al., 2013; Phillips & Bana e Costa, 2007). Correspondingly, it reduces the failure risk (Vinodh & Swarnakar, 2015) by avoiding having to deal with multiple conflicting objectives, insufficient details, and inappropriate resource allocation (Phillips & Bana e Costa, 2007). Davis (2003) claimed that prioritization outcomes not only affect the level of improvement activities but could extend to affect an organization's competitiveness in the market.

Although there are numerous methods to select and prioritize improvement initiatives, such as Pareto analysis (Larson, 2003), project selection matrix (Pande, Cavanagh, & Neuman, 2000), Quality Function Deployment (QFD) (LePrevost & Mazur, 2005), AHP (Kırış, 2014), cost-benefit analysis, cause-effect matrix, Pareto priority index (Marriott et al., 2013), and Theory Of Constraints (Mariscal, Herrero, & Toca Otero; Pyzdek, 2014), some decision makers still select improvement initiatives based on subjective preferences such as on experience, common sense, feelings and beliefs, which can lead to significant risks of improvements failure and undesirable cost (Hu, Wang, Fetch, & Bidanda, 2008; Kirkham et al., 2014).

2.4.1 Prioritizing improvement initiatives

The literature contains various articles which elaborate on prioritizing improvement initiatives in various industries. Table *2-2* briefly discusses methods in the literature to prioritize improvement initiatives.

Table 2-2: Methods in the literature to prioritize improvement initiatives in various industries

Publication (Author (s), year)	Organization type	Methodology and result
(LePrevost & Mazur, 2005)	Information Technology	Applied QFD to identify and prioritize the customer needs in order to evaluate and prioritize the internal IT projects according to complexity and value added. The prioritization helped the organization to assign the appropriate resources to each project. The case study proved that the approach assisted the organization to reduce ineffective multitasking and achieve higher completion rate for projects.
(Water & Vries, 2006)	Information Technology	The AHP was used to select from among a number of improvement projects in an IT-oriented company. The results demonstrated a strong contribution of AHP to transfer of knowledge and better communication among different disciplines in the enterprise. The AHP is a simple tool to apply in the decision-making process and can be helpful to explore inconsistent judgments.
(Jung & Sang-Gyu, 2007)	Service	Presented a framework to categorize potential projects to enable project prioritization and execution systematically. The framework used SS methodology

Publication (Author (s), year)	Organization type	Methodology and result
		to map the projects in term of process capability and process controllability measure. The framework was validated through a case study of the customer satisfaction improvement program.
(Hsieh et al., 2012)	Service	The study utilized AHP and Failure Mode and Effect Analysis (FMEA) to rank the project to select SS projects. It includes: project identification, project value assessments, project complexity assessments, and prioritization. The framework evaluated the projects based on its value and complexity. The value criteria consisted of costs, financial returns, and impact on workforce behavior. While the complexity criteria consist of: data availability, scope, and potential risk.
(Marriott et al., 2013)	Manufacturing	The research proposed integrating two commonly used approaches in the industry, Process Activity Mapping (PAM) and FMEA, and developed a methodology to prioritize improvement projects, activities or initiatives in low volume-high integrity product manufacturing based on two business objectives: cost reduction and high product quality. The results of the case study validated the effectiveness of the methodology in dealing with the complexity of selecting and prioritizing feasible improvement projects.
(Eghtesady, Brar, & Hall, 2013)	Healthcare	Developed objective prioritization approach to prioritize improvement initiatives in pediatric cardiology and cardiac surgery. The approach accounts for frequency and relative contribution of quality measurement of morbidity in a low mortality setting. Data collection and analysis was conducted in 35 hospitals. A prioritization scheme was developed based on procedure’s ranking using four metrics: Mortality, any adverse event, readmission and length of the stay.

Publication (Author (s), year)	Organization type	Methodology and result
(Abbasianjahromi & Rajaie, 2013)	Construction	The research presented a hybrid methodology to select a project in construction environments. It applied fuzzy case-based reasoning to pre-screen the project before adding it to the existing portfolio then select the most suitable project using zero-one linear goal programming.
(F. K. Wang et al., 2014)	Film printing	Developed a hybrid framework by integrating DEMATEL, ANP and VIKOR to select Six Sigma (SS) improvement projects. Applicability of the framework was proved using a case study in a Taiwan film printing industry. The framework enabled the scholars to analyze the current gap between performance and targeted level based on influential network relation map and improving the gap in each dimension
(Vinodh & Swarnakar, 2015)	Manufacturing	Employed a hybrid fuzzy MCDM approach to select the optimal Lean Six Sigma (LSS) project in an Indian automotive manufacturing components organization. The methodology combined fuzzy DEMATEL, ANP, and TOPSIS to prioritize LSS projects and choose the optimal project. A case study validated the practicality of the methodology to reduce the risk of failure.
(Holmes, Jenicke, & Hempel, 2015)	Education	The study presented a framework to select among SS opportunities in an academic setting. It suggested using the weighted scorecard approach to choose the most efficient project in utilizing time and campus's resources.

2.4.2 Available prioritization models for business excellence

This section reviews the literature regarding improvement opportunities prioritization in business excellence models. It provides an analysis and insight into their applicability, reliability, and validity in a healthcare setting.

2.4.2.1 Prioritization Model 1

Dodangeh and Yusuff (2011) developed a model to prioritize and choose EFQM areas for improvement using Multi Attribute Decision Making (MADM). MADM is a Multi-Criteria Decision Making (MCDM), or Multiple Criteria Decision Analysis (MCDA), approach. MCDM mainly works to facilitate the solving of conflict decision problems with multiple constraints (Winston, 1994). It is a holistic framework that starts with problem structuring and knowledge exchange, identifying of criteria preferences and importance, and then evaluation of the alternatives. MCDM's results enable decision makers to select the optimal alternative (Santos, Belton, & Howick, 2002; Tavana & Sodenkamp, 2010). The literature demonstrates an extensive use of MCDM approaches in practice (Atici, Simsek, Ulucan, & Tosun, 2015; Broekhuizen, Groothuis-Oudshoorn, Til, Hummel, & Ijzerman, 2015; Canas, Ferreira, & Meidutė-Kavaliauskienė, 2015). MCDM methods assist decision-makers in selecting, ranking, sorting, or describing alternatives (Atici & Ulucan, 2011); however, the challenge is to select appropriate methods from the wide range available (Marsh, Lanitis, Neasham, Orfanos, & Caro, 2014). MCDM problems can be aligned into two categories:

- Multiple Objective Criteria Making (MOCM)
- Multiple Attribute Decision Making (MADM)

The MOCM approach aims to select the best alternatives that satisfy the objective function under certain constraints in continuous space (Farahani, SteadieSeifi, & Asgari, 2010). The literature frequently mentions goal programming and multi-objective optimization as the most popular tools to solve MOCM problems (Herath & Prato, 2006). MADM, on the other hand, focuses on selecting the best alternatives in discreet space. It is frequently used in prioritization and criteria's interaction (Dodangeh & Yusuff, 2011; Farahani et al., 2010). Some of the most popular MADM techniques are Analytical Hierarchical Process (AHP), Analytic Network Process (ANP), Simple Additive Weighting (Akyürek, Sawalha, & Ide), and Multi Attribute Utility Theory (MAUT) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) (Farahani et al., 2010).

Dodangeh and Yusuff (2011) developed a method to evaluate and prioritize areas for improvement in an EFQM model. Figure 4-2 illustrates the algorithm they used.

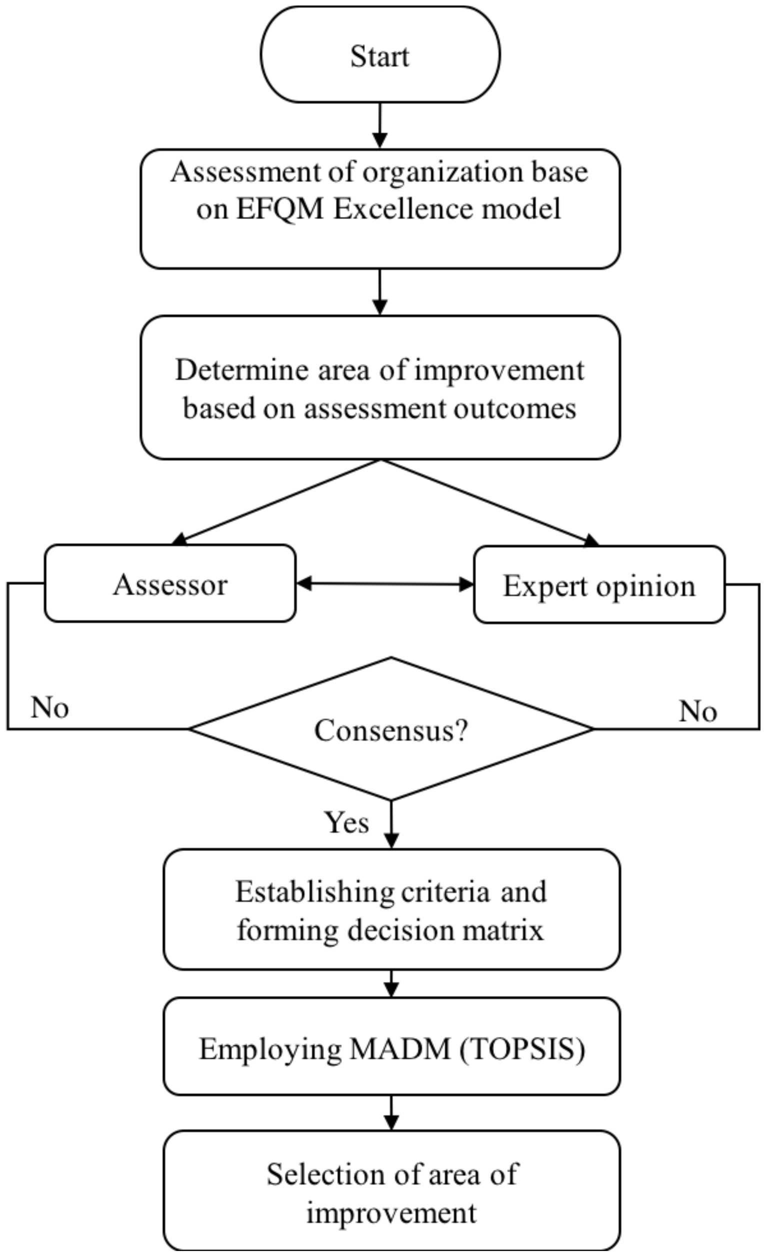


Figure 2-4: Dodangeh and Yusuff (2011) algorithm for areas of improvement selection

The scholars first conducted a self-assessment based on the EFQM model then got assessors' and experts' consensus on the areas of improvement to focus on. Then defined criteria and formed a decision matrix. The researchers established the following four criteria to evaluate the alternatives:

1. Importance: this criterion involves the degree of importance the improvement has to the organization.
2. Cost: the criterion lets the experts evaluate if the area of improvement is within the organization's budget and financial resources.
3. Time: this criterion considers the required time to perform the area of improvement since a shorter time can allow the organization to achieve its objectives faster.
4. Gap: this criterion represents the difference between the current state and the desired state. In the research, they calculated it by finding the difference between the assessment score and the perfect score in the EFQM model

The scholars conducted a case study in mega car manufacturing. The board of expert included the directors of marketing and sales, engineering, logistics, production, and management while the panel of assessors consisted of three assessors. The experts and the assessors defined the area of improvements. After evaluating each area of improvement based on the four criteria above a decision matrix was constructed; then the TOPSIS technique was applied to rank the areas of improvement.

TOPSIS is a quantitative approach to identify the closest alternative to an ideal solution and the farthest to an anti-ideal solution (Deng, Yeh, & Willis, 2000). Hwang and Yoon introduced this technique in 1995 (García-Cascales & Lamata, 2012). It can be used to find the optimal solution or to rank alternatives (Deng et al., 2000; Mehralian, Nazari, Rasekh, &

Hosseini, 2016). Simplicity and ease of use are the strongest advantage of TOPSIS. The method doesn't require a high level of expertise and knowledge and, regardless of number of the associated attributes or problem size, the calculation steps remain the same (Mehralian et al., 2016; Velasquez & Hester, 2013). The steps in TOPSIS are outlined below (Khan & Maity, 2016):

Step 1: Build a decision matrix (A), where rows denote the alternatives and columns represent the qualities associated with each alternative base on attribute evaluation.

$$\boldsymbol{A} = \begin{bmatrix} a_{11} & a_{1j} & \dots & a_{1n} \\ a_{i1} & a_{ij} & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{mj} & \dots & a_{mn} \end{bmatrix} \tag{1}$$

Step 2: find the normalized decision matrix (**N**) through the following equation:

$$a_{ij}' = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}} \tag{2}$$

where a_{ij}' is the normalized value.

Step 3: obtain the Weighted Normalized Decision (**Y**) by multiplying the normalized value with the weight assigned to the attribute.

$$\boldsymbol{Y} = w_j \, a_{ij}' \tag{3}$$

Step 4: calculate the best and worst alternative using the following equations.

1. Best ideal alternative

$$A^B = \{(max\, y_{ij} | j \in J);(min\, y_{ij} | j \in J') \; i = 1, 2 \dots n\} \tag{4}$$

$$A^B = \{y_1{}^B, y_2{}^B \dots, y_n{}^B\}$$

2. Worst ideal alternative

$$A^w = \{(min\, y_{ij} | j \in J); (max\, y_{ij} | j \in J')\ i = 1, 2 \dots n\} \quad (5)$$

$$A^w = \{y_1{}^w, y_2{}^w \dots, y_n{}^w\}$$

where J is the set associated with positive quality features and J' that associated with negative ones.

Step 5: calculate the Euclidean distance of each alternative from the best and worst solutions.

1. Euclidean distance from the best ideal alternative

$$S_i^B = \sqrt{\sum_{j=1}^{n} (y_{ij} - y_j{}^B)^2} \quad , i = 1,2,3 \dots n \quad (6)$$

2. Euclidean distance from the worst alternative

$$S_i^w = \sqrt{\sum_{j=1}^{n} (y_{ij} - y_j{}^w)^2} \quad , i = 1,2,3 \dots n \quad (7)$$

Step 6: compute relative closeness to the ideal solution.

$$c = \frac{S_i^B}{S_i^B + S_i^w}\ ;\ i = 1,2,3 \dots m; 0 < C < 1 \quad (8)$$

Step 7: based on relative closeness to the ideal solution, rank the alternatives, where the highest ratio indicates the best alternative.

There is a significant amount of literature dealing with the TOPSIS method and its applications. It has been used in supply chain management (Azadfallah, 2016), academia manufacturing (Khan & Maity, 2016), engineering (Yukseloglu, Yayla, & Yildiz, 2015), environmental management (Sabokbar, Hosseini, Banaitis, & Banaitiene, 2016), and business and marketing (Senel, Senel, & Sariyar, 2012). Many works in the literature used TOPSIS to confirm the results of other MCDM methods (Velasquez & Hester, 2013) due TOPSIS rank reversal phenomenon which is one of the famous drawback of TOPSIS (García-Cascales & Lamata, 2012). This phenomenon yields to a dramatic change of alternatives rankings with the exclusion or inclusion of new alternatives. Another drawback of TOPSIS that it doesn't account for the relative importance between the Euclidean distances. As shown in equation eight, it simply sums both distances without considering their importance (Lai, Liu, & Hwang, 1994). Moreover, attributes weighting and keep a consistency in judgment can be difficult in TOPSIS and it could dramatically affect the solution (Velasquez & Hester, 2013).

2.4.2.2 Prioritization Model 2

Dodangeh et al. (2011) repeated the same algorithm used in model 1 and only changed the method used. Instead of TOPSIS, they utilized Fuzzy Multiple Criteria Decision Making (FMCDM). Dr. Lotfi Zadeh first introduced fuzzy logic in 1965. The primary purpose of fuzzy logic is to enhance the interaction between human and computer; since humans tend to use linguistic assessment instead of numerical values (Mehralian et al., 2016). In fuzzy logic, linguistic variables are associated with fuzzy numbers to characterize the meaning of the used linguistic information (Zhang & Liu, 2011). Fuzzy logic has the ability to deal with insufficient information and uncertain data (Velasquez & Hester, 2013). Dodangeh et al. (2011) argued that combining Fuzzy logic with MCDM to prioritize areas of improvement can lead to a more robust solution as the classical MCDM may face constraints in real application due to vagueness of information.

Fuzzy MCDM methods were introduced to solve inaccessible problems with the classical MCDM (Abdullah, 2013). Fuzzy MCDM contains different methods to find rankings, relative importance, and design mathematical programming (Słowiński & Teghem, 1990). Fuzzy MCDM has been applied successfully in multiple criteria decision making in several cases. Extensive literature discusses the use of Fuzzy MCDM in supply chain management (Keshavarz Ghorabaee, Zavadskas, Amiri, & Turskis, 2016; Yayla, Oztekin, Gumus, & Gunasekaran, 2015; Zeynali, Aghdaie, Rezaeiniya, & Zolfani, 2012). Other scholars have used Fuzzy MCDM to determine the level of fulfillment of design requirements. For example, Karsak (2004) proposed using fuzzy multiple objective programming to overcome the subjectivity of QFD and determine the level of design requirements achieved.

The steps in Fuzzy MCDM are:

Step 1: define universe set, membership function and form decision matrix

The first step is to define the linguistic variables and the corresponding numerical values. The universe set (U) includes {1,2,3,4,5,6,7,8,9} associated with nine fuzzy membership functions {extremely low, very low, low, slightly low, medium, slightly high, high, very high, extremely high}, respectively. Considering the bell-shaped membership function and the following equation, a fuzzy MCDM matrix is formed.

$$\mu_A(x) = \frac{1}{1+d\,(x-c)^2} \tag{9}$$

where:

x = element of the universe set

c = standard score for determining verbal value

d = value to determine membership function shape (d in this case = 0.2)

The fuzzy degree of gap criteria is found using the following equation:

$$\mu_A(x) \cap \mu_B(x) = min(\mu_A(x), \mu_B(x)) \quad , X \in U \tag{10}$$

where:

μ_B is the fuzzy target of the EFQM model.

Step 2: find the utility of decisions, calculated using:

$$A_i = \{ (\overline{c_1} \cup a_{i1}) \cap (\overline{c_2} \cup a_{i2}) \cap \ldots (\overline{c_m} \cup a_{im})\} \tag{11}$$

Step 3: convert fuzzy output to crisp utility and rank

Using the center of gravity method and equation below, scholars convert the fuzzy output to crisp utility.

$$Z = \frac{\sum_{j=1}^{n} M(x_j).x_j}{\sum_{j=1}^{n} M(x_j)} \tag{12}$$

Then, based on the crisp utility value, areas of improvement are ranked.

The result of this model completely contradicted with model 1 result, even though it used the same methodology and the same case study. Thus, the scholars called to build more prioritization models to test the efficiency of the current models.

2.4.2.3 Prioritization Model 3

In a study performed by Ezzabadi, Saryazdi, and Mostafaeipour (2015), a new integrated approach was proposed to improve an organization’s excellence. The study aimed first to improve business performance evaluation using fuzzy logic, then to determine high priority areas of improvement using the AHP and the Operation Research (OR) model. The AHP is the most famous of the MCDA methods (Broekhuizen et al., 2015; Kang & Lee, 2007). It can be applied to multiple objectives and multi-criteria problems (Saaty, 1994). In 1980, Thomas L. Saaty introduced AHP to measure tangible and intangible criteria through pairwise comparisons and expert judgments to determine alternatives' level of importance or preference (Godwin, 2000). The AHP converts complex systems to a hierarchical structure, where the goal is placed at the first level, followed by criteria at the next level then alternatives at the lowest level (Armacost, Hosseini, & Pet-Edwards, 1999). It uses a nominal scale to perform pair-wise comparisons between alternatives at each hierarchical level (Velasquez & Hester, 2013). Although this method requires quite a bit of data, the literature doesn't consider it a data-intensive method compared to the other MCDM methods.

The AHP is popular in the literature and it has been used in many fields, such as government, healthcare, education and business (Godwin, 2000; Kaili, 2016; Maruthur, Joy, Dolan, Shihab, & Singh, 2015). For example, Godwin (2000) conducted systematic analysis of IT outsourcing decisions using AHP. Maruthur et al. (2015) explored the feasibility of using AHP methods in determining which diabetes type 2 medication to be prescribed. According to this study, AHP utilization improved the consistency and transparency among the stakeholders in medical decision making. Others have studied applying AHP to assess and prioritize criteria in several professions (Armacost et al., 1999; Kaili, 2016). Also, various literature has reviewed the results of AHP integration with multi-objective tools in order to consider both tangible and nontangible criteria to solve MODM problems (Fazlollahtabar, Mahdavi, Ashoori, Kaviani, & Mahdavi-Amiri, 2011; Kırış, 2014; Ozfirat, Ozfirat, Malli, & Kahraman, 2015).

The major drawbacks of AHP, according to Velasquez and Hester (2013), is the interdependence between alternatives and criteria due to the use of pairwise comparisons and their susceptibility to rank reversal. It has also been pointed out that the subjective evaluation of the experts that is part of AHP can lead to inconsistency in judgment (Ishizaka & Labib, 2009; Velasquez & Hester, 2013). Various researchers (Pöyhönen, Hämäläinen, & Salo, 1997; Stillwell, Von Winterfeldt, & John, 1987) have argued that different hierarchal structures can lead to different rankings. For example, a criterion tends to have more weight if it is associated with a large number of sub-criteria.

As a part of their research, Ezzabadi et al. (2015) conducted a case study at the Yazd Regional Electricity Company in Iran. After re-evaluating the business performance scores using fuzzy logic, the scholars identified areas of improvement based on the sub-criteria's score and verify it based on experts' opinions. In order to prioritize the area of improvement the scholars conducted the following steps:

Step 1: Find sub-criteria's weight based on expert opinion

First, Ezzabadi et al. (2015) converted the EFQM system to a hierarchal structure, as illustrated in Figure 2-5, where EFQM's main criteria are AHP's criteria and the sub-criteria are used as alternatives. The analysis did not include the results criteria as the organization was not willing to define any improvement projects for that category.

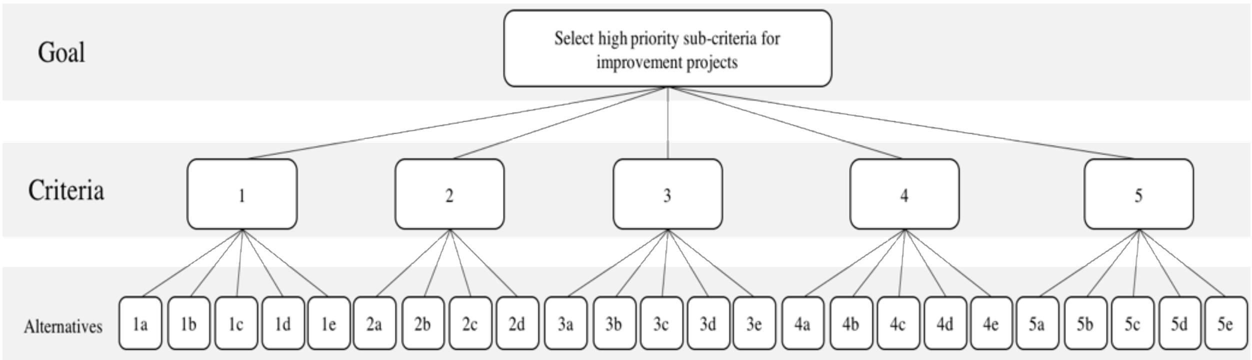


Figure 2-5: Ezzabadi et al. (2015) hierarchal structure

Then these scholars developed questionnaires to compare between criteria and sub-criteria. In their questionnaires, researchers used linguistic variables which were then converted to numerical values. For instance, the experts could categorize the importance of criteria as very low, low, partly low, medium, partially high, high and very high, corresponding to the numerical values of 1/4, 1/3, 1/2, 1, 2, 3, and 4 respectively. In the sub- criteria comparison only five levels were used (very low, low, medium, high and very high), which later on were converted to (1/3, 1/2, 1, 2, 3) scores, respectively.

The matrix of the pairwise comparison below was formed based on the geometric mean of experts' input from the results of the questionnaire.

$$\boldsymbol{A} = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{i1} & a_{i2} & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} \tag{13}$$

Where $a_{ij} = 1/\ a_{ji}$ and the main goal of AHP is to find aji $\cong \frac{w_i}{w_j}$

According to Saaty (1994) the pairwise comparison matrix is

$$\boldsymbol{W} = \begin{bmatrix} \frac{w_1}{w_1} & \cdots & \frac{w_1}{w_j} & \cdots & \frac{w_1}{w_n} \\ \frac{w_i}{w_1} & \cdots & \frac{w_i}{w_j} & \cdots & \frac{w_i}{w_n} \\ \vdots & & \vdots & \ddots & \vdots \\ \frac{w_n}{w_1} & \cdots & \frac{w_n}{w_j} & \cdots & \frac{w_n}{w_n} \end{bmatrix} \tag{14}$$

By solving the next equation as an eigenvalue problem, the relative weight of the sub-criteria's weight can be found.

$$\mathbf{W} \times \mathbf{w} = \begin{bmatrix} \mathrm{w_1/w_1} & \dots & \mathrm{w_1/w_j} & \dots & \mathrm{w_1/w_n} \\ \mathrm{w_i/w_1} & \dots & \mathrm{w_i/w_j} & \dots & \mathrm{w_i/w_n} \\ \vdots & & \vdots & \ddots & \vdots \\ \mathrm{w_n/w_1} & \dots & \mathrm{w_n/w_j} & \dots & \mathrm{w_n/w_n} \end{bmatrix} \begin{bmatrix} \mathrm{w_1} \\ \mathrm{w_i} \\ \vdots \\ \mathrm{w_n} \end{bmatrix}$$

Step 2: Find the distance between the current and targeted score

Next Ezzabadi et al. (2015) calculated the target function (Z), which is the total sum of multiplication of weight given by organizational experts (W_i') with the sub-criterion variable (JúNIOR & ASANO) as shown in the following equation.

$$Z = \sum_{i=1}^{24} w_i' \times SC_i \tag{15}$$

Note that 24 is the number of sub-criteria of the enabler section in the EFQM model, which was only included in the analysis.

Step 3: Sub-criteria prioritization

The final step was the computational procedure to find the index for each sub-criteria. The scholars used the following equations:

$$F_w = W_m \times W_E \tag{16}$$

where W_m is the sub-criterion weight from the model, W_E the sub-criterion weight given by the expert from step 1 (using AHP), and F_W the final weight of the sub-criterion.

$$Index = D_{OR} \times F_w \quad (17)$$

Where D_{OR} is the distance between the current score and the target score obtained in step 2.

Based on the sub-criterion's index, the scholars were able to prioritize the sub-criteria where a high index is an indication of high priority.

2.4.2.4 Prioritization Model 4

In Iran, Herat, Noorossana, parsa, and Serkani (2012) developed a model to select an improvement project in the healthcare sector. The research utilized a hybrid algorithm of the Decision Making Trial and Evaluation Laboratory (DEMATEL) and the Analytical Network Process (ANP). The scholars first gave experts a questionnaire to determine the causal relationship between the EFQM nine criteria in healthcare; then, based on those relations, they ranked the improvement projects using ANP. Fifteen experts participated in the questionnaire to draw the causal relation between the nine criteria.

DEMATEL was introduced by Battelle Memorial Institute in Geneva research center between 1971 and 1972 (Gabus & Fontela, 1972) to identify a mutual relationship in a complex system. It also illustrates the interdependencies between criteria and identifies the main causal factors which have a substantial effect on the rest of the system (Bacudio et al., 2016; Lin, 2013). In recent years, DEMATEL has been employed to identify the interrelationships among factors. For example, Lin (2013) used it to investigate the influential factors in green supply chain management. Bacudio et al. (2016) identified the barriers to implementing industrial symbiosis networks in Laguna, Philippines. In this case, DEMATEL permitted the scholars to analyze the barriers of implementation by studying the cause and effect relationship between the barriers. Govindan and Chaudhuri (2016) also applied DEMATEL to evaluate the interconnectedness between risk factors faced by third party logistics service providers.

The ANP is an extension of AHP (Saaty, 2006). The AHP builds hierarchal structure and assumes independence between elements, but in real cases elements are dependent and interact with others. Thus, Saaty (2006) developed ANP to overcome this shortcoming (Wudhikarn, Chakpitak, & Neubert, 2015). ANP has a nonlinear form and network structure to handle both feedback and dependency (Velasquez & Hester, 2013). Numerous studies have applied ANP in the decision-making process. Abdi (2012) applied ANP to select product family formation while considering market and manufacturing requirements. Lee, Kim, Cho, and Park (2009) employed ANP to identify the core technologies in network technology and the relative importance and impact of the used technologies on each other. In other studies, ANP was used in combination with other methods. Wang (2012) combined ANP with DEMATEL to consider dependence and feedback in selecting the appropriate interactive trade strategy. This scholar applied the hybrid framework to international business practices in Taiwan. However, despite its apparent usefulness, a few researchers have criticized ANP for not including uncertainty and probability information, which they claim may lead to inappropriate conclusions (Hsu & Pan, 2009; Wey, 2008). Thus, various research has proposed integrating ANP with methods that account for uncertainty to overcome this drawback. In their work to choose between newly developed formula for roof tiles, Wudhikarn et al. (2015) suggest using Monte Carlo analysis with inputs before applying ANP in order to consider uncertainty inherited from the input data.

Herat et al. (2012) developed a methodology to investigate interdependencies between EFQM criteria in healthcare using the DEMATEL technique, and then they incorporated ANP to prioritize ten improvement projects. Below, the DEMATEL steps to establish the network relationship are presented; then the method for applying ANP to obtain the prioritization is presented.

The DEMATEL analysis consists of six step according to Lee, Huang, Chang, and Cheng (2011):

Step 1: scale of evaluation identification

This step involves examining the degree of participants' perceptions of the impact of a particular dimension through pairwise comparisons between dimensions. The scholars used a scale of 0,1,2,3, and 4 to represent no impact, low impact, medium impact, high impact, and extremely high impact, respectively.

Step 2: direct-influence matrix **Z** construction

Based on the output of step 1, a direct-influence matrix **Z** is constructed to represent the degree of influence of factor *i* on factor *j*.

$$\boldsymbol{Z} = \begin{bmatrix} z_{11} & z_{1j} & \cdots & z_{1n} \\ z_{i1} & z_{\mathrm{ij}} & \cdots & z_{\mathrm{j}n} \\ \vdots & \vdots & \ddots & \vdots \\ z_{n1} & z_{n\mathrm{j}} & \cdots & z_{nn} \end{bmatrix}$$

Step 3: normalized direct-relation matrix **X** construction

Using the following equations, the direct-relation matrix **X** is found.

$$\boldsymbol{X} = s\,.\boldsymbol{Z} \qquad (18)$$

$$s = min\left(\frac{1}{\underset{1<i<n}{max}\ \sum_{j=1}^{n}|z_{ij}|}, \frac{1}{\underset{1<j<n}{max}\ \sum_{i=1}^{n}|z_{ij}|}\right)\ \ i,j = 1,2,\ldots,n \qquad (19)$$

Step 4: total-influence matrix **T** construction

$$\boldsymbol{T} = X + X^2 + X^3 + \cdots + X^m = X(I - X)^{-1} \tag{20}$$

where **I** is the identity matrix

Step 5: relation and prominence identification

This step involves summing **T** rows and columns to obtain the relation and prominence using the following equation, where d_i represents the direct and indirect influence over the other criteria, which indicates factors impacting the others. Then r_j represents the other criteria degree of impact, indicating factors that are influenced by others. The $d_i + r_j$ values called prominence and indicate the strength of the relationship between the factors, whereas the $d_i - r_j$ values are called relations and indicate the strength of the impact among factors.

$$\boldsymbol{D} = [d_i]_{n\times1} = \left(\sum_{j=1}^{n} t_{ij}\right)_{n\times1} \tag{21}$$

$$\boldsymbol{R} = \left[r_j\right]'_{1\times n} = \left(\sum_{j=1}^{n} t_{ij}\right)'_{1\times n} \tag{22}$$

Step 6: Network Relation Map (NRM) construction

NRM is a graphical representation to illustrate the interdependencies and relations between factors. Herat et al. (2012) in his model set a threshold value for the criteria's effect to reduce the complexity of NRM.

The ANP technique is performed in four basic steps (Herat et al., 2012; Lee et al., 2011; Saaty, 2006)

Step1: network structure formation

This step involves constructing a network to represent interrelationships between clusters and within elements. Herat et al. (2012) obtained their network structure (Figure 2-6) through the decisions makers brainstorming session to define the criteria, sub-criteria, and alternatives.

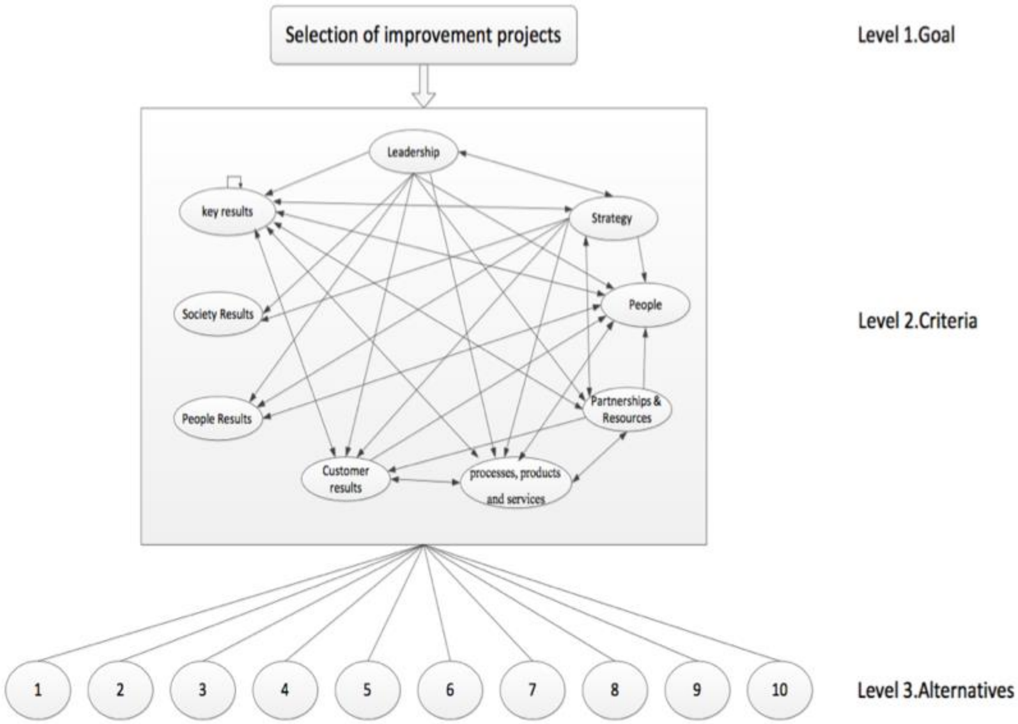


Figure 2-6: Herat et al. (2012) network structure

Step 2: pair-wise comparison

The pair-wise comparison is performed with respect to criteria and between elements in a cluster to determine the importance weight of each factor. Similar to in AHP, decision makers use a scale of nine points to form the pair comparison matrix and factors' weight vector.

Step 3: super matrix formation

The super matrix concept is similar to the Markov chain process in queuing theory matrix. It can be expressed as a parallel to Markov chain process in queuing theory (Saaty, 1996). The super matrix aims to find global prioritization within the system taking into consideration the interdependent influences.

Step 4: best alternative selection

The best alternative or prioritization of alternatives can be determined using the weight of importance of each alternative obtained in the super matrix.

2.4.2.5 Prioritization Model 5

In their research to assess the safety culture in the Spanish nuclear industry, Mariscal et al. (2012) carried out an assessment using staff evaluation and a RADAR matrix to identify the main areas of improvement needed and quantify the safety culture's dimensions. The scholars believed that this quantification could be used as a reference to develop a mechanism to prioritize future improvements.

Table 2-3: Summary of the available models

(Author, year)	**Organization type**			**Method**						**Basis of the evaluation**		**Entities involved in decision making**		**Quantifying the impact of uncertainty**		**Defining criteria**	
	Healthcare	Manufacturing	Service	TOPSIS	Fuzzy MCDM	RADAR matrix	AHP/ANP	Operation Research	DEMATEL	Self-assessment	External Assessment	Managers and Focus group	Other stakeholders	No	Yes	No	Yes
(Dodangeh & Yusuff, 2011)		X		X						X		X			Y		Y
(Dodangeh et al., 2011)		X			X					X		X		N			Y
(Ezzabadi et al., 2015)			X				X	X		X		X		N		N	
(Herat et al., 2012)	X						X		X	X		X		N		N	
(Mariscal et al., 2012)		X				X				X		X		N		N	

2.5 Healthcare

The healthcare sector is a compound system of entities, processes, and activities with high-volume throughput. The involvement of a wide range of stakeholders increases the complexity of requirements, prioritization, and evaluation criteria. Kanji and Moura e Sá (2003) summarized the key stakeholders (Figure 2-7) in typical healthcare organizations.

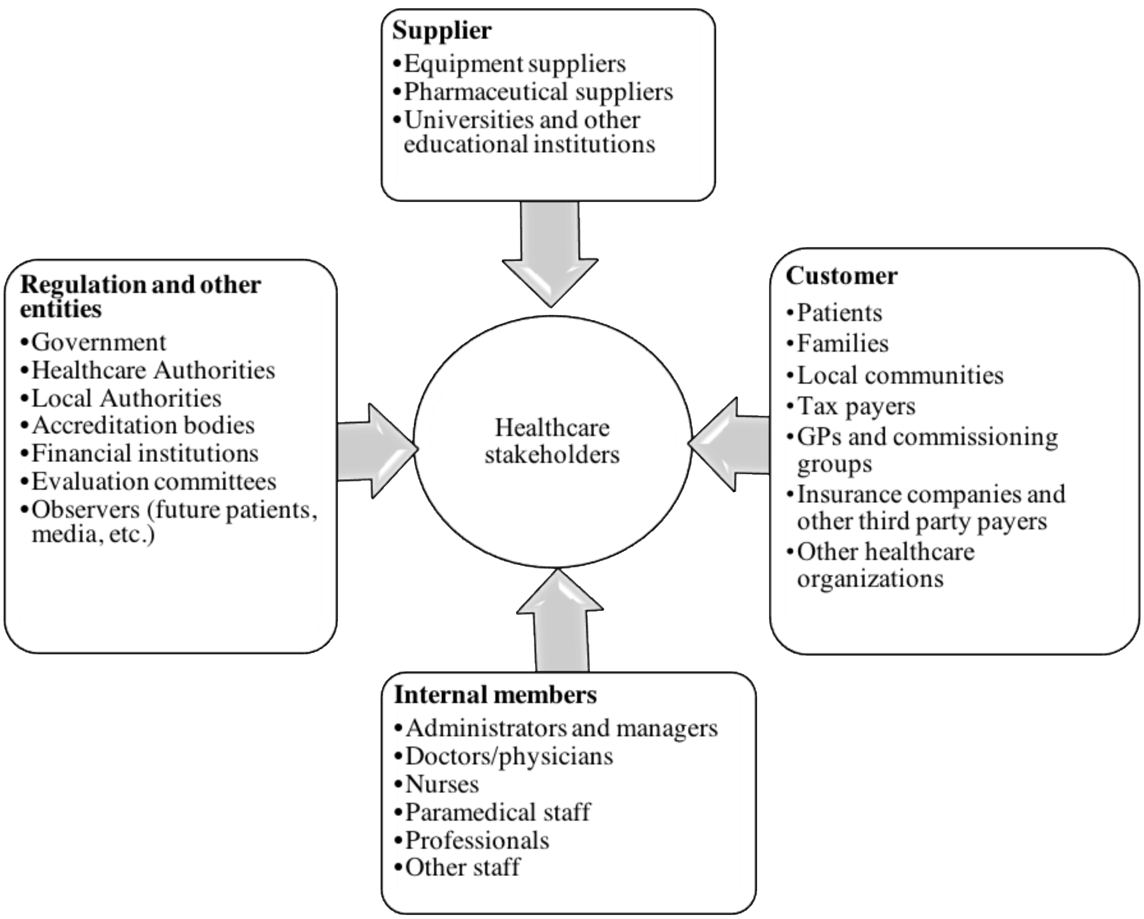


Figure 2-7: Healthcare key stakeholders

Adapted from Kanji and Moura e Sá (2003)

In addition to having to deal with a diversity of stakeholders, healthcare providers are encountering growing pressure in the form of rising costs of health care delivery, financial constraints, difficulty of retaining and recruiting good professionals, and escalating standards of education and living. The former factors yield to high patient's expectations, medical breakthroughs, stronger competition, availability of alternative providers, stricter laws and government regulations, public and private monitoring, information availability, and easier accessibility (Cheng Lim & Tang, 2000; Kunst & Lemmink, 2000; Lin, 1995; Rivers, 1999; Short, 1995; Theodorakioglou & Tsiotras, 2000).

Accordingly, the healthcare industry has undergone a profound transformation in the last two decades (Smith, 2013) and worldwide restructuring to improve service efficiency and cope with patients' high expectations (Say Yen & Shun, 2015). An internal reformation is taking place rather than addition of new facilities. The new services delivery focus on the improving healthcare culture, organizational learning, staff behavior adjustment, and workforce engagement (Smith, 2013). The Institute of Medicine in 2001 established six characteristics to improve the healthcare sector: improve the system's effectiveness, improve safety, provide patient-centered services, increase efficiency, deliver equitable services, and deliver timely services. Among these six characteristics, delivering patient-centered services has been the driving force behind numerous healthcare reengineering efforts. The main objective of patient-centered services is to design valuable, practical and desirable services from a patient's perspective as the patients and their experiences are the core values of healthcare system (Lee, 2011). Therefore, various quality initiatives improvements were carried to achieve these objectives

2.5.1 Quality initiatives in healthcare

Over the years, the healthcare industry has adopted several manufacturing approaches to enhance service performance and the patient experience. Methodologies like lean thinking, Six Sigma (SS), TQM, and business process reengineering, continuous improvement has been deployed to improve healthcare quality and its operational excellence (Crossland, Janamian, & Jackson, 2014; Macinati, 2008; Ovretveit & Staines, 2007). Recent literature has focused on studying the advantages of adopting quality initiatives in healthcare.

According to Jayasinha (2016), the LSS can help improve the patient experience. Jayasinha implemented LSS in a pediatric clinic to eliminate waste and non-value added processes in order to decrease the clinical cycle time to 90 minutes and raise patient satisfaction from 87% to 95%. In Taiwan, Yeh, Lin, Su, and Wang (2011) analyzed LSS's impact on the medical process of acute myocardial infarction. The LSS decreased door-to-balloon (D2B); D2B is the interval time of patient arrival to emergency cardiac care until the first balloon inflation in the primary percutaneous coronary intervention; by 58.4% and increased efficiency by 1.6%. Also, it reduced the average inpatient stay by three days. A similar case study was conducted in the UAE by Ellahham, Aljabbari, Harold , Raji, and AlZubaidi (2015). Here, the D2B process decreased from 75.9 to 60.1 minutes and the percentage of patients who were treated within 90 minutes increased to 96% comparing to 73% before the improvement

In their review, Mason, Nicolay, and Darzi (2015) assessed the utilization of Lean and Six Sigma in surgery; 88% of the studies demonstrated an enhancement in pre-operation, operation, and in-patient settings. The enhancements included operative complication reduction, ward-based harm reduction, mortality reduction, outpatient efficiency optimization, cost reduction, and decreased length of stay. Nevertheless, the scholars promoted conducting further studies to understand the bias. Huang, Li, Wilck, and Berg (2012) claim that hospitals can reduce their costs via LSS. They support their hypothesis through presenting several case studies of hospitals around the world which had adopted LSS. In general, each healthcare facility reported a reduction in operational costs, improvements in service quality, and an increased profit margin. In Italy, Macinati (2008) validated the relation between adopting TQM system and Italian healthcare performance.

Many scholars have concluded that LSS can reduce waste to allow for faster and better processes in various divisions in the healthcare system. Gijo and Antony (2013) addressed resolving the issue of long wait times in the Outpatient Department (OD) using LSS. Their application of LSS in this setting decreased the average waiting time to 24.5 minutes (SD=9.27 min) as compared to 57 minutes (SD=31.15 min) before LSS adoption. Agarwal et al. (2016) demonstrate that LSS can positively impact the cardiac catheterization laboratory's process. This study applied LSS to improve on-time patient arrival, on-time physician arrival, optimal turn-time to 56.6% from 43.6% in 2009, on-time start to 62.8% comparing to 41.7% in 2009, and optimal physician downtime to less than 35 minutes.

Patient-centered services are uniquely essential in healthcare to increase patient satisfaction. Scholars like Otani, Waterman, Faulkner, Boslaugh, and Dunagan (2010) found a proportional relation between patient satisfaction and willingness to return to the same provider and to recommend the provider to a family or a friend. The same study concluded that patient satisfaction has a great influence on healing and recovery. Adopting quality initiatives can improve the patient experience (Jayasinha, 2016), raise market competitiveness (Yeh et al., 2011), reduce costs, and increase the profit margin (Huang et al., 2012).

The World Health Organization (WHO) published a report in 2006 indicating that quality improvement in healthcare is a shared responsibility of healthcare service providers, policy and strategy development authorities, and communities and service users. Any critical activity requires engagement from the entire system. The relationships between the three entities are illustrated in Figure 2-8.

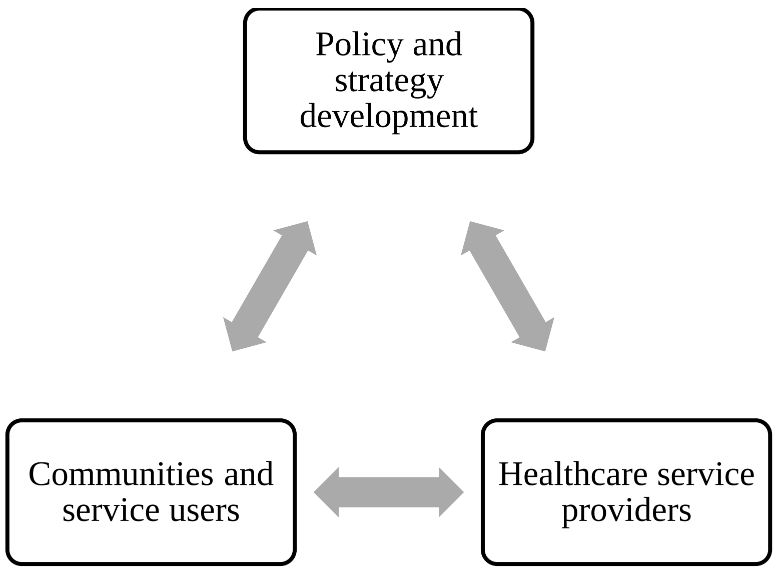


Figure 2-8: Roles and responsibilities in quality improvement

Adopted from (WHO, 2006)

2.5.1 Quality initiative challenges in healthcare

There is an intense scientific interest in healthcare's ability to diffuse quality initiatives. However, while the healthcare sector is considered to be one of the scientific rich sectors and is among the top knowledge-based institutions (Berwick, 2003), it encounters significant challenges to implementing quality initiatives. Abdallah (2014) listed challenges that can encounter quality initiatives implementation in healthcare after surveying sixty representatives of eighteen hospitals in Jordan and compare it with literature. The study revealed challenges related to the healthcare system, medical staff education and training, manager and physician impact, law and system's regulation, and culture resistance.

Regardless of the promising benefits healthcare can experience from adopting quality initiatives, various studies have reported less than successful scenarios and some factors, consistently identified as ‘challenges,’ prevent wider adoption and may explain the failure of quality initiatives in healthcare. See Table 2-4 for a summary.

The majority of scholars declare that hospital culture is the main challenge for quality initiative implementation. According to Pocha (2010) getting different stakeholders to “buy into” the approach is the toughest part because quality initiative changes their daily routines and introduce new delivery methods. Bhat, Gijo, and Jnanesh (2014) showed that manager and employee resistance are the main challenges for improving registration process in Indian hospitals. The resistance is due to the lack of knowledge and education about quality initiative methodology.

Abdallah (2014) indicate that medical staff believe that managers and physicians are a possible barrier to quality initiatives. In hospitals, physicians have more authority and power than other employees. Hence, insufficient physician involvement is a major obstacle to successful quality initiatives implementation (Pocha, 2010). In her research, Mosadeghrad (2015) concluded that Iranian healthcare has a medium TQM success due to lack of quality management systems and a low level of workforce engagement.

Radnor and Boaden (2008) argued that hospital systems complexity and stakeholder involvement are significant challenges. Patients in hospitals are significantly involved in the majority of the processes while customers in the manufacturing sector only assess the final products. Hence, quality improvements in hospital are associated with more human elements, has more variability, and it is complex to adopt (Bandyopadhyay & Coppens 2015). Also, due to hospital complexity, it is not easy to identify processes and indicators or define the defect to be measured (Bhat, Gijo, & Jnanesh, 2016; Laureani, Brady, & Antony, 2013).

Another challenge is the medical staff education and training. Insufficient background knowledge of industrial engineering tools can limit quality initiative adoption (Bhat et al., 2016). The literature revealed that physicians and nurses showed a significant appreciation for statistics as a problem-solving tool, but they lack the interest to utilize it in their routines (Chiarini & Bracci, 2013). Also, even though nurses are considered to be a significant quality asset, black belt training is only available for physicians (Abdallah, 2014; Chiarini & Bracci, 2013).

After studying two public healthcare organizations in Italy, Chiarini and Bracci (2013) revealed that quality initiative implementation could also be restricted by laws and regulations. In many countries, including Italy, politicians impact the strategic planning in public healthcare, which can influence quality initiatives adopting. Also, quality initiatives projects are partially cost-reduction–driven, but public hospitals are not required to link their improvement projects to financial results.

Table 2-4: Challenges to implementing quality initiatives in healthcare

Challenge	**Corresponding measurement instruments**
Culture Resistance	Kanji and Moura e Sá (2003), Pocha (2010), , Bhat et al. (2014)
Lack of knowledge and education	Bhat et al. (2014), Bhat et al. (2016); Chiarini and Bracci (2013); Knapp (2015)
Organizational structures	Pocha (2010), Abdallah (2014), Mosadeghrad (2015), Radnor and Boaden (2008), Chiarini and Bracci (2013)
Lack of senior management commitment	Kanji and Moura e Sá (2003), Mosadeghrad (2015)
System complexity	Radnor and Boaden (2008), Bhat et al. (2014), Bandyopadhyay and Coppens (2015)
Laws and regulations	Chiarini and Bracci (2013), Abdallah (2014)

2.5.2 Business excellence models in healthcare

Kanji and Moura e Sá (2003) argued that the transformation of healthcare orientation has led it to be more patient-oriented, have more cost control, improve effectiveness and efficiency, and increase the pressure to adopt business excellence models. The excellence models, in general, and EFQM, in particular, are widely implemented in healthcare (Moeller & Sonntag, 2001; Nabitz et al., 2000; Vallejo et al., 2007) in parallel with other improvement initiatives to improve their business excellence scores.

In order to determine the actual utilization of business excellence models in healthcare, a systematic review was conducted through searching and screening the literature between 1999-2016 using MEDLINE, ProQuest, Web of Science, and Google Scholar. First, all articles were tabulated according to the author and publication year. A lot of studies were related to the search interest, but if a study was about quality improvement in healthcare without using business excellence it was eliminated. The evaluation and analysis of the context of the articles led to them being grouped into five categories, presented in *Table 2-5*.

with the related literature. Note that the search used ‘business excellence’ in general as a keyword and then another search was conducted using the three major excellence models as search terms. Some keywords were helpful as synonyms for healthcare to broaden the search and get more results, including ‘hospitals’, ‘medical’, ‘pharmacy’, ‘dental’, ‘therapy’. The five main categories are:

1- Category 1: Literature discussing applications of BEMs in healthcare

The articles discuss the experience of implementing excellence models in the entire organization, department or even at the project level as an assessment tool or a guideline to prepare plans and strategies. Those articles also demonstrate whether the models were able generate noticeable outcomes in healthcare. For example, Moeller and Sonntag (2001) illustrated the German health services experience gained through evaluating their system against EFQM. The article shared best practices, success factors, limitation, barriers and lessons learned. The scholar concluded that the model is generic enough to cover all areas in healthcare. Vallejo et al. (2007) described the implementation of EFQM in a psychiatric hospital ward. The study proved the possibility of its implementation and cited a positive impact on clinical personal communication and involvement. Sabella, Kashou, and Omran (2015) assessed the quality of management practices in 51 hospitals in Palestine using the MBNQA model. The study reported that the hospitals got an excellent score in administration practices and lower scores in areas like human resources, information analysis, and performance results.

2- Category 2: Literature examining the suitability and reliability of BEMs for healthcare environment

The articles in this category focus on conducting an investigation to examine whether BEMs are suitable for the healthcare environment; they analyze the reliability and applicability of the models. For instance, Gené-Badia, Jodar-Solà, Peguero-Rodríguez, Contel-Segura, and Moliner-Molins (2001) explored the applicability and reliability of EFQM in primary healthcare systems in Spain. Their results supported the hypothesis of applicability and reliability and showed approximately similar result of self-evaluation and external evaluation. In the UK, Stewart (2003) tested whether EFQM was a suitable model within the pharmacy department at Salford Royal Hospitals. The study demonstrated that EFQM could enhance the quality of service and provide a structured approach within the pharmacy department. Abdallah, Haddadin, Al-Atiyat, Haddad, and Al-Sharif (2013) investigated the applicability of EFQM in the Jordanian healthcare organization. The Scholars noted that once. The study proved that EFQM is an applicable model in Jordanian hospitals, but hospital personnel should have proper training.

3- Category 3: Literature comparing BEMs with existing programs and systems in healthcare

The articles in this category attempt to compare excellence models with existing healthcare systems and accreditation programs to ensure no conflicts occur between both. Donahue and vanOstenberg (2000) compared Joint Commission International (JCI) with four quality models, including EFQM. The study points out that both JCI and other quality models employ standards and external reviewers in the evaluation process. The JCI program and EFQM are both cited as frameworks for quality management and empowering quality leadership. However, the JCI is shown to allow international comparison, which is not the case for excellence models due to model variation between countries. Foster et al. (2007) compared MBNQA with the existing clinical microsystem in USA. The study aimed to discover if both frameworks examine similar success characteristics. The scholars remark that the success characteristics of both frameworks related to high performance. However, the study claimed that leadership, work system, and service process are emphasized more in MBNQA while process improvement, information, performance results and information technology are stressed more in clinical microsystems stress.

4- Category 4: Literature discussing Critical Success Factors (CSFs) for excellence models in healthcare

This group of articles concentrated on studying CSFs that facilitate successful excellence models implementation in healthcare. D'Souza and Sequeira (2011) empirically proved that information systems have an impact on healthcare organization performance in South India through exploring the relationship between information systems and MBNQA criteria. The research concluded that a higher technological utilization has a dramatic impact on quality performance in healthcare organizations. Matthies-Baraibar et al. (2014) tried to determine the relationship between employee satisfaction and EFQM implementation. With a participation of 30 healthcare providers in Osakidetza, the Basque public health service, the scholars studied nine dimensions of employee satisfaction between 2001-2010. The results illustrated a significant correlation between EFQM implementation and employee satisfaction in organization level dimensions. Hochenedel and Kleiner (2016) argued that excellence in healthcare is not only associated with providing exceptional services to patients, but also should include the ability to meet government laws and regulations as well as insurance and accreditation requirements. These scholars believe that healthcare organizations can achieve excellence by hiring and retaining top talent, utilizing technology and increasing BEMs adoption efforts to reduce costs.

5- Category 5: Literature discussing the Integration/modification of BEMs to suit the requirements of healthcare.

Although the excellence models can bring outstanding benefits to healthcare, various scholars still argue that excellence models are too generic for healthcare and question their ability to cover all clinical aspects. The literature in this category includes that in which scholars propose a modification or integration with other models to overcome those shortcomings. This category also include articles that discuss the use of EFQM to enhance an existing program. Vallejo et al. (2006), for example, proposed using the Performance Assessment Tool for quality improvement in Hospitals (PATH) conceptual framework, developed by the WHO Regional Office for Europe, to develop an EFQM specific healthcare framework. Kim and Oh (2012) established mental healthcare evaluation criteria based on MBNQA and verified the evaluation model causality. In Spain, López-Viñas et al. (2014) illustrates how an adaptation of the EFQM and the accreditation model of acute care hospitals yielded a higher degree of compliance with standards, smoother communication between accreditation organizations and accredited centers, and greater professionalism of the audit process.

6- Prioritizing business excellence's improvement initiatives in the context of healthcare

This topic was only covered by only one study conducted by Herat et al. (2012). This model was discussed in detail in section 2.4.2.

Table 2-5: Business excellence in healthcare

The use of Business excellence models in healthcare system	Related literature
Business excellence's applications in healthcare	Naylor (1999), Nabitz et al. (2000), Jackson (2000), Moeller and Sonntag (2001), Sanchez et al. (2006), Del Rio et al. (2006), Usha, Bhimaraya, and Shalini (2007); Vallejo et al. (2007), Foster and Pitts (2009); Vernero, Nabitz, Bragonzi, Rebelli, and Molinari (2007), Mena Mateo, de la Fuente, Cañada Dorado, and Villamor Borrego (2009), Foster and Pitts (2009), Ana I. Marques et al. (2011), Rowland-Jones (2012), Dehnavieh et al. (2012), Mundongo et al. (2014), Favaretti et al. (2015), Sabella et al. (2015)
Business excellence's suitability for healthcare	Gené-Badia et al. (2001), Moeller and Sonntag (2001), Stewart (2003), Abdallah et al. (2013), Van Schoten, De Blok, Spreeuwenberg, Groenewegen, and Wagner (2016)
Business excellence in comparison to healthcare programs and systems	Donahue and vanOstenberg (2000), Foster et al. (2007)
Business excellence CSFs in healthcare	Jackson (2000), Fraser and Olsen (2002), Kanji and Moura e Sá (2003), Studer (2004), Stuart-Kregor (2006), Zimring, Augenbroe, Malone, and Sadler (2008), Matthies-Baraibar et al. (2014), Hochenedel and Kleiner (2016)
Business excellence model modification/integration to suit healthcare requirements	Holland and Fennell (2000), Vallejo et al. (2006), Kim and Oh (2012), Moreno-Rodrı´guez, Cabrerizo, Pérez, and Martı´nez (2013), López-Viñas et al. (2014), Tekic, Majstorovic, and Markovic (2015)
Prioritizing Business excellence improvement initiatives in healthcare	Herat et al., 2012

2.5.3 The benefits BEMs can bring to healthcare

The BEMs can bring enormous benefits to healthcare performance (Dehnavieh et al., 2012; Mundongo et al., 2014). Thus, it is essential to evaluate the impact on healthcare performance and illustrate the associated index(es). Table 2-6 presents a summary of a systematic review of the literature related to Business Excellence's impact on the healthcare system.

According to the literature, the dominant reason for adopting a business excellence model in healthcare is to increase patient satisfaction. This increase has been shown in several studies. For example, Sanchez et al. (2006) showed an increase in patient satisfaction rate from 93.1% to 96.2% in the emergency department and outpatient clinics after applying an EFQM model in Basque Health Service. In Trento Healthcare Trust, Favaretti et al. (2015) reported 94% patient satisfaction with physicians and nurses, an increase of 6% in 2009 when compared to results from a 2002 survey. An increase in overall patient satisfaction rate was also found, to 89% and 84% for inpatient and outpatient care, respectively, compared to 77% and 70% in 2002.

Business excellence affects various clinical and non-clinical processes. Vallejo et al. (2007) showed an increase in the admission rates in the psychiatric ward from 282 in 2003 to 297 in 2005 and an increase of 12.5% in scheduled admissions (17% in 2003 and 29.5% in 2005). The same study reported a decrease in emergency re-admissions from 20 to 12 after adopting EFQM. Different studies have examined the Length of Stay (LoS) rate before and after business excellence implementation and reported a rate reduction. Vallejo et al. (2007) showed a reduction in average LoS from to 14.8 days in 2003 to 13.8 days in 2005. Sanchez et al. (2006) also reported a reduction in LoS, from 6.1 day in 2000 to 5.9 days in 2003. Stahr (2001) indicated an average of one day of LoS for dedicated hernia services in Salford Royal Hospitals NHS Trust compared to an average of 3.6 days before the improvement project was implemented. Another index is service accessibility, which is the time it takes to receive care services. Sanchez et al. (2006) found that the length of time on the surgical waiting list in Basque Health Service was reduced to 53.8 days in 2003 comparing to 57.1 days in 2001. The scholars also reported a reduction in patient wait times to receive specialized care to 61.1% comparing to 63.1%. Stahr (2001) also assessed the average time for patients to access surgical spinal services and reported that patients had to wait less than three weeks after a BEM was implemented, comparing to a wait of up to 2.5 years previously. The researchers also reported a massive improvement in the time needed for acute stroke patients to access a rehabilitation bed, moving from less than 72 hours as compared to up to ten weeks before the improvement. Favaretti et al. (2015) stated that with the adoption of BEM in the Trento Healthcare Trust, 85% of the patients in the emergency room received care in an hour and increased the consultations duration and the time physicians spent with the patients. Sanchez et al. (2006) observed that primary care medical consultation duration increased from 7.4 in 2001 min to 8.5 min in 2003.

The impact of BEM extends to the healthcare system work environment. In general, improvement initiatives based on business excellence have been shown to enhance employees' satisfaction index (Favaretti et al., 2015). In the Congo, Mundongo et al. (2014) stated that more than 50% of the employees in a laboratory were satisfied after excellence implementation, an increase of 11% compared to 2005. Leigh et al. (2005) concluded that business excellence improved the qualified nurses' retention rate and increased the level of confidence and competence among newly qualified nurses. Moreover, the new environment led to further scientific and Congress involvement. Vallejo et al. (2007) reported that using EFQM in the psychiatric ward enabled the hospitals to increase the number of scientific papers published from six in 2003 to nine in 2005; moreover, 52 posters and presentations were presented at Congresses in 2005 comparing to only nine in 2003. A similar result was presented by Stahr (2001); the number of Salford Royal Hospitals NHS Trust peer-reviewed research publications increased from 148 a year to 185 a year.

In addition, hospitals with business excellence adoption allow more emphasis on creating a learning environment. Vallejo et al. (2007) stated that the number of training courses received or given by professional staff increased after business excellence implementation; the received courses increased from 12 to 35 and given courses from 17 to 23. In the healthcare system, personal safety is a top priority, and with business excellence adoption occupational injuries recorded a reduction of 53.7 per 1000 staff in 2009 comparing to 69.2 in 2003 (Favaretti et al., 2015). On the communication side, Stahr (2001) reported better communication throughout the Salford Royal Hospitals NHS, with an increase of 40% (before 40% and 80% after the improvement) and easier accessibility to a manager with an enhancement of 82% comparing to 46%.

Business excellence has also been shown to influence the relationship between the healthcare system and the surrounding environment. Favaretti et al. (2015) found that the Trento Healthcare Trust was able to reduce hospital waste to 1.39 kg per day in 2009 versus 2.04 kg per day in 2003 after introducing a BEM. Stahr (2001) and Vallejo et al. (2007) studied the correlation between business excellence adoption in healthcare and positive media reports. Stahr (2001) reported 81% positive reports after adoption in contrast to 76% before. In addition, Vallejo et al. (2007) noticed an improvement in the daily average website hits and increase in the appearance in the media after business excellence adoption.

The literature does not provide much evidence of a positive impact of business excellence adoption in healthcare in terms of financial results, but it does report some impact. The lack of information could be linked to confidentiality regulations in healthcare, which prevent revealing any specific financial data. Stahr (2001) did identify that the business excellence improvement programs enabled Salford Royal Hospitals NHS Trust to recruit 88 nurses while allowing it to reduce the recruitment cost by € 30, 205 in 2001. The NIST (2015) claimed that Baldrige's criteria enabled the health system to save $12 million over the past four years only from supply chain management.

Table 2-6: Impact of business excellence in healthcare and related indices

Impact and related index(es)	Corresponding research
Increase patient satisfaction	
– Increase patient satisfaction index	(Sanchez et al., 2006), (Favaretti et al., 2015)
Improve clinical and non-clinical operations	
– Increase the admission rate	(Vallejo et al., 2007)
– Reduce Length of Stay rate	(Sanchez et al., 2006),(Stahr, 2001), (Vallejo et al., 2007)
– Reduce readmission rate	(Vallejo et al., 2007)
– Improve service accessibility	(Stahr, 2001), (Sanchez et al., 2006), (Favaretti et al., 2015)
– Increase consultation duration	(Sanchez et al., 2006)
Improve work environment	
– Improve employee satisfaction index	(Favaretti et al., 2015), (Mundongo et al., 2014)
– Improve nurses' retention rate	(Leigh et al., 2005)
– Improve scientific and congress publication rate	(Stahr, 2001), (Vallejo et al., 2007)
– Improve accessibility to managers	(Stahr, 2001)
– Increase training course rate	(Vallejo et al., 2007)
– Reduce occupational injuries rate	(Favaretti et al., 2015)

Impact and related index(es)	Corresponding research
Improve societal impact	
– Reduce hospital waste rate	(Favaretti et al., 2015)
– Increase positive media reports	(Stahr, 2001), (Vallejo et al., 2007)
Improve financial result	
– Reduce recruitment cost	(Stahr, 2001)
– Reduce supply chain cost	(NIST, 2015)

2.5.4 Decision making in healthcare

Stafinski, Menon, McCabe, and Philippon (2011) defined decision making as a process to examine different alternatives to reduce uncertainty and achieve the desired results. The decision-making process can be a complex process due to the consideration of various aspects such as timelines, budget vs. return value, potential methodologies, sociological impact, stakeholder involvement, and accountability. Consequently, the decision-making process in a complex and dynamic system like healthcare can be even more stressful (Ozcan, 2005) since it involves both clinical and non-clinical aspects (Akyürek et al., 2015).

In their literature review, Akyürek et al. (2015) aimed to identify the most cited factors in the last five years that have impacted the decision-making process in a healthcare organization. The scholars only included articles discussing the decision-making process from a managerial perspective and so did not include clinical decisions. The study identified seven factors and categorized them into the most and least cited, as shown in Table 2-7. It should be noted that the fact that a factor is commonly is not an indication of its importance but is merely an indication of its occurrence in the literature.

Table 2-7: Factors affecting decision making in healthcare

Adapted from: (Akyürek et al., 2015)

Most cited factors	Least cited factors
• Knowledge based decision making • Organizational and institutional environment • The use of technology and analytic tools	• Decision supporting tools and models • Financial resources • Time and delegation • Shared decision making

2.6 Proposed approaches

This section presents the background of the approaches used in the proposed framework in chapter 4 and the applications of those methods in the literature.

2.6.1 Stakeholder involvement

A variety of stakeholders in any system produce deviation in knowledge content and orientation. Although experts bring scientific knowledge based on the scientific model and their personal experience, other stakeholders can bring new insights and information into the decision-making process. A comparison of expert and stakeholder knowledge as laid out by Edelenbos, van Buuren, and van Schie (2011) is presented in Table 2.8. It reveals the different values, perspectives, and motivation that input from experts and stakeholders can bring.

Table 2-8: The difference between experts and stakeholder knowledge

adapted from (Edelenbos et al., 2011)

	Expert knowledge	**Stakeholder knowledge**
Norm for knowledge production	Scientific validity	Social validity
Warrant for useful knowledge	Positive peer review and prospects for publication	Level of fit with the business, local experiences and interests
Core business	Scientific research: systematic and objectified observations	Daily life, private business, defending certain societal interests
Criteria for success	Validating scientific hypotheses; expanding the knowledge domain	Support for one's own interests and agenda

There are couple of tools are useful for visualizing and analyzing stakeholders' influence. The power/interest matrix introduced Mendelow (1991) in the early nineties has been widely adopted as a mapping tool since its introduction. The power/interest matrix is a two-by-two matrix, where stakeholders are categorized into four groups: players, who should be managed closely; the subject, who should be kept satisfied; the context setter, who should be kept informed; and the crowd, who should only be monitored. Power represents stakeholder influence over the project to shape while interest represents stakeholders' attractiveness to the project (Sova et al., 2015).

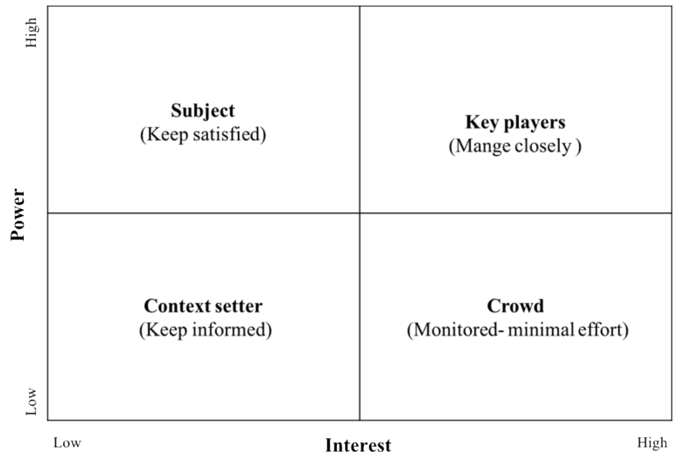


Figure 2-9: Power/Interest matrix.

Adapted from (Mendelow, 1991)

2.6.2 Fuzzy Delphi method

During the 1950s and 1960s the RAND cooperation developed the Delphi method to obtain consensus among group of experts (Dalkey & Helmer, 1963). It offers a systematic way to collect the judgment of a panel of experts on a certain subject through multiple iterations of questionnaires and controlled feedback with respect to the responses from each round (Delbecq, Van de Ven, Gustafson, Van de Ven, & Gustafson, 1975). The Delphi method attempts to achieve consensus in judgment while minimizing group pressure, influence of dominant power entities, and irrelevant communication (Strand, Carson, Navrud, Ortiz-Bobea, & Vincent, 2017).

Typically, Delphi method start with open questions. Then, as more data is collected, questions become more structured so as to verify previous consensus and test propositions (Birdsall, 2003). Most often, a Delphi study includes three iterations of data collection controlled by a researcher (Brady, 2015). The data collection may be conducted through email or mail to ensure experts' anonymity, allow collection of a dispersed sample, and allow convenient time for response (Cavana, Delahaye, & Sekaran, 2001). After each iteration, researchers analyze the responses and provide feedback to the participants (Birdsall, 2003; Dalkey & Helmer, 1963). Additional iteration is sometimes required if consensus has not been reached (Brady, 2015).

The Delphi method has a wide variety of applications in various fields. For example, Feiming Chen and Yuqing Liu (2016) investigated the key risk factors in developing mobile e-commerce in China using eDelphi methods. Henderson, Johnson, and Moodie (2016) developed a conceptual framework of parent-to-parent support for parents raising a child with hearing problems. The scholars employed Delphi method to obtain stakeholders' opinions and feedback and achieve consensus on the framework components. Strand et al. (2017) applied the Delphi method as a tool for environmental valuation. In the study, more than 200 experts from 37 countries participated to estimate the willingness-to-pay value per each country to protect the Amazon rainforest.

Ishikawa et al. (1993) proposed the Fuzzy Delphi Method (FDM) by deriving the method from fuzzy set theory and the conventional Delphi technique. Although the Delphi method is an effective method for capturing expert opinion, Ishikawa et al. (1993) indicated that to reach acceptable consensus level it may take several repetitive surveys, which probably will reduce the response rate and increase survey cost and time. The researchers suggested integrating a fuzzy set with the conventional Delphi Method to resolve the fuzziness of common understanding, based on expert judgements (Noorderhaben, 1995), thereby reducing the number of surveys rounds required. This makes the process more time- and cost-effective (Ishikawa et al., 1993; Kuo & Chen, 2008), as the process can handle multi-level and multi-solution decision problems and perform simple calculations (Kuo & Chen, 2008).

Since FDM's introduction, various scholars have evolved the technique and utilized it in different applications. For example, Kuo and Chen (2008) obtained the key performance indicators for service industry mobility in Taiwan through applying FDM. Hsu, Lee, and Kreng (2010) established a systematic approach to selecting among proposed technologies. These scholars employed FDM to identify critical factors to selecting among different waste lubricant recycling technologies by interviewing experts in the field. Tahriri, Mousavi, Haghighi, and Dawal (2014) developed a conceptual framework for an effective supplier selection process. Gil-Lafuente, Merigó, and Vizuete (2014) applied the FDM to understand the luxury resort hotel industry in Taiwan and Macao and build an assessment system. The FDM enabled these scholars to obtain the importance of each evaluation criteria based on a group decision.

The literature demonstrates that there are different approaches used in FDM to aggregate experts' knowledge, execute deffuzzification, and reach a consensus. Those approaches depend on the application and the researcher's objectives (Habibi, Jahantigh, & Sarafrazi, 2015).

2.6.3 Fuzzy logic

Dr. Zadeh introduced the fuzzy set concepts in the mid-1960s as a way to consider classes with uncertain boundaries. Fuzzy logic was derived from fuzzy set theory (Zadeh, 1965). Unlike classical methods, which use binary variables for evaluation, the fuzzy logic approach combines linguistic variables with numerical data to enhance the interaction between human and computers while accounting for uncertainty in judgment (Mehralian et al., 2016; Velasquez & Hester, 2013). The advantage of using fuzzy logic is the ability to take linguistic variables, which are vague and difficult to interpret, and convert them to numerical data. This capability enables researchers to create a mathematical model based on human subjective judgment (Fuli, Yandong, Yun, Xu, & Lin, 2016).

Typical fuzzy interface system architecture is comprised of four main modules: a fuzzifier, an inference engine, a fuzzy knowledge base, and a defuzzifier. Figure 2-10 illustrates fuzzy inference architecture and its main components (Shin & Xu, 2009).

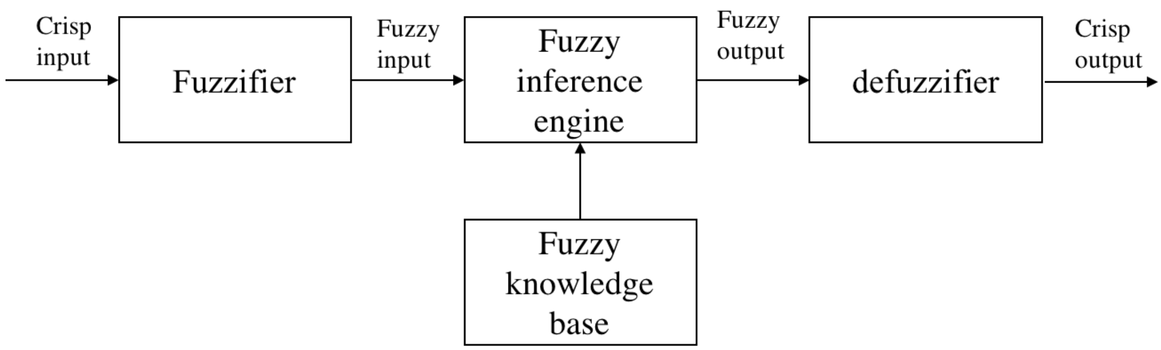


Figure 2-10: Typical architecture of Fuzzy Inference System

Sources: (Shin & Xu, 2009).

Crisp input (numerical data) is fed into the first component of the system, the fuzzifier, which translates the numerical data (crisp) into a fuzzy value. Fuzzy values are characterized by linguistic variables, like “very low”, “low”, “moderate”, “high”, “very high” and so on. Each of these linguistic terms has a certain level associated with the membership function. The membership function implies the degree of certainty that an element belongs to a fuzzy set. Most often, the membership function has the shape of a triangle, trapezoid or Gaussian function (Shang & Hossen, 2013). The fuzzy inference engine, the second component in the system, then maps the fuzzy input into fuzzy output based on the rules stored in the knowledge base. A fuzzy knowledge base is basically a database that contains rules to establish the relationship between different variables (Shin & Xu, 2009). In general, the rules are expressed using either a Mamdani model or a Takagi-Sugeno model (Dodangeh et al., 2011). Lastly, the defuzzifier converts the fuzzy output into crisp output using the same membership function used in the fuzzifier (Shin & Xu, 2009). There are various techniques for defuzzification, such as centroid-based Euclidean distance, left and right fuzzy ranking, bisector of an area, and mean of maximum (Fuli et al., 2016).

Because fuzzy logic can be used to represent human judgments, , it enjoys widespread use in many industries and contexts. For example, in their recent work Danladi, Puwu, Michael, and Garkida (2016) utilized fuzzy logic to build a load forecasting guide for electrical power generation, transmission, and distribution to investigate the parameter impact on electrical load. In another recent work, Ahmed, Elkhatib, Adly, and Ragai (2016) proposed using fuzzy logic to improve the detection algorithm of wireless sensor network accuracy in sensitive facilities.

Fuzzy logic is commonly used to enhance the selection process in diverse situations. Al-Hawari, Khrais, Al-Araidah, and Al-Dwairi (2011) proposed using fuzzy logic to select scanner among different model of laser scanners. The fuzzy set and fuzzy rules were used to convert linguistic experts' opinions into assessment ratings to reduce the effect of bias and subjective judgments. Khrais, Al-Hawari, and Al-Araidah (2011) also used fuzzy logic to select the best prototyping techniques for use in prototype production, where the highest overall efficiency is based on both static and dynamic factors. In an enterprise setting, Zandi and Tavana (2012) introduced a novel fuzzy group multi-criteria model to evaluate and select among different enterprise architectures to capture multiple decision makers' intuitive preferences.

In the healthcare domain, Idowu, Ajibola, Balogun, and Ogunlade (2015) developed a fuzzy logic model to monitor heart failure risk through assessing risk indicators using patients assessment. In breast cancer research, a fuzzy logic-based model was developed in breast cancer patient management to identify the gene and validate its signatures to allow personalized medicine (Kempowsky-Hamon et al., 2015). In the context of healthcare management, Pan (2011) studied the patients' perceived values to enhance patients' satisfaction and loyalty. The researchers developed a fuzzy logic-based model to capture the patients' perceptions toward the hospital. The model discovered that patients' top values are quality of provided care and physician competence.

2.6.4 Fuzzy VIKOR

Fuzzy VIKOR is the integration between traditional VIKOR and Fuzzy set. The traditional VIKOR is an MCDM technique. It stands for VlseKriterijumska Optimizacija I Kompromisno Resenje in the Serbian language, which means multiple criteria optimization (Babashamsi, Golzadfar, Yusoff, Ceylan, & Nor, 2016). Real problems are often characterized by non-commensurable and conflicting criteria and there a possibility that no solution can satisfy all the criteria at once (Yang, Shieh, & Tzeng, 2013). Thus, Serafim Opricovic in 1998 developed VIKOR to take decisions associated with non-commensurable and conflicting criteria problems in a discrete environment to find compromise solutions and derive a compromise ranking list based on closeness to the ideal solution (Opricovic, 1998).

The steps of the Fuzzy VIKOR method are described below (Zhu, Hu, Qi, Gu, & Peng, 2015).

Step 1: Find the best ideal solution f_i^* and worst solution f_i^- values of all criterion function, where i = 1,2,3…n.

If the creation is a benefit:

$$\widetilde{n_{ij}} = \frac{\tilde{f}_i \ominus \widetilde{x_{ij}}}{\tilde{f}_i^{\;*} - \tilde{f}_i^{\;-}} \quad (23)$$

$with\ f_i^* = max_j\, \tilde{x}_{ij}\ , f_i^- = min_j\, \tilde{x}_{ij}$

If the creation is a cost:

$$\widetilde{n_{ij}} = \frac{\tilde{x}_{ij} \ominus \tilde{f}_i}{\tilde{f}_i^{\;*} - \tilde{f}_i^{\;-}} \quad (24)$$

With $f_i^* = min\, \tilde{x}_{ij}\ , f_i^- = max\, \tilde{x}_{ij}$

Step 2: Compute group utility values (S_j) and individual regret (R_j).

$$\tilde{S}_j = \sum_{i=1}^{n} \widetilde{w}_i\, \widetilde{n_{ij}} \quad (25)$$

$$R_j = max_i\left(\widetilde{w}_i\, \widetilde{n_{ij}}\right) \quad (26)$$

where j = 1,2,3…m and w_i is the weight of each criteria to represent its relative importance.

Step 3: Compute a compromise index (Q_j)

$$\tilde{Q}_j = v\left(\frac{\tilde{S}_j - \tilde{S}^*}{\tilde{S}^- - \tilde{S}^*}\right) + (1 - v)\left(\frac{\tilde{R}_j - \tilde{R}^*}{\tilde{R}^- - \tilde{R}^*}\right) \quad (27)$$

where $\tilde{S}^* = \min_j \tilde{S}_j\ , \tilde{S}^- = \max_j \tilde{S}_j\ , \tilde{R}^* = \min_j \tilde{R}_j\ , \tilde{R}^- = \max_j \tilde{R}_j$, v is the weight of the strategy or maximum group utility; normally v takes a value of 0.5, but it can be any value between 0 and 1.

Step 4: Sort the S, R, and Q values in decreasing order to rank the alternatives. Three lists should be obtained.

Step 5: Find a compromise solution among the alternatives that has the lowest value of Q and satisfies the following conditions simultaneously:

1- Acceptable advantage (**C1**): $Q_j(a^{"}) - Q_j(a') > DQ$, where a' is the first alternative based on the compromise solution, $a^{"}$ is the second alternative in the Q list, and $DQ = \frac{1}{m-1}$, where m is the number of alternatives.

2- Acceptable stability in decision making (**C2**): the best alternative should also be ranked first by S and / or R.

In many cases both conditions can't be attained. Thus, a set of compromise solutions are derived accordingly:

If **C1** is not satisfied, then a set of compromise solutions should be explored with maximum value of m.

$$Q_j(a^M) - Q_j(a') < DQ \quad (28)$$

If **C2** is not satisfied, then a' and $a^{"}$ are the compromise solutions.

Since VIKOR's introduction, various scholars have evolved the technique and utilized it in different applications. Yang et al. (2013) designed an information security risk control assessment model by combining VIKOR, DEMATEL and ANP. The model utilized VIKOR to solve the problem of conflicting criteria the shows dependences. The study proved that the framework could assist the IT managers to validate the effectiveness of the adopted risk controls methods. Zhu et al. (2015) integrated VIKOR with AHP and rough numbers to evaluate a design concept in the process of new product development. Fuli et al. (2016) developed a model to determine the best alternative for end-of-life vehicle recycling providers considering economic, environmental and social factors. The model relied on Fuzzy VIKOR rank to select the best choice. The scholars integrated fuzzy logic with VIKOR to deal with the ambiguous and qualitative human judgment . Ipekci Cetin and Cetin (2016) applied VIKOR to evaluate and rank the European Union and candidate countries with respect to women's education and employment.

In the literature, VIKOR is frequently compared to TOPSIS (Hacioglu & Dincer, 2015; Opricovic & Tzeng, 2004; Tzeng & Huang, 2011) which is another method of multi-criteria optimization. However, the comparisons reveal that both techniques have different approaches in the normalization and aggregation functions (Babashamsi et al., 2016; Tzeng & Huang, 2011). As stated before in this chapter, TOPSIS solutions should be the closest to the best alternative and the farthest from the worst alternative. However, this calculation doesn't consider the importance of the distances (Lai et al., 1994). In contrast, VIKOR introduces an aggregation function to represent the distance from the ideal solution. It aggregates the criteria and relative importance of the criteria and finds the balance between individual and total satisfaction (Tzeng & Huang, 2011). Also, Babashamsi et al. (2016) believed that TOPSIS is more suitable for a risk-averse decision maker.

2.7 Literature review summary

In review, this chapter presents a view of the literature conducted by other researchers directly related to the area of study. It introduces the definitions of Total Quality Management (TQM), its promising benefits, and the factors necessary for successful TQM implementation. It then discusses business excellence models and the global trend to move from TQM to business excellence. The chapter examines topics like project prioritization and its impact and presents findings from previous studies regarding prioritizing improvement project techniques. In addition, the literature review presents in detail the available models to prioritize improvement opportunities in the context of BEMs in different industries and compares their approaches. The review also discusses the processes involved in quality improvement, decision making, and business excellence models in healthcare. The chapter ends by reviewing Delphi methods, the fuzzy logic system and VIKOR and their application in the literature.

2.8 Research Gap analysis

Five existing models were developed by Dodangeh et al. (2011); Dodangeh and Yusuff (2011); Ezzabadi et al. (2015); Herat et al. (2012); Mariscal et al. (2012) to prioritize performance excellence model areas for improvement

In the Dodangeh and Yusuff (2011) model, the scholars used MADM and the TOPSIS technique to prioritize BEM areas for improvement. The scholars defined four general criteria: improvement importance, cost, time, and the gap between the current and ideal score. Internal experts evaluated the area for improvements based on the four criteria, which were determined by internal self-assessment. Dodangeh et al. (2011) repeated the the previous methodology again and change the used technique to Fuzzy MCDM (See Table 2-9). The research results contracdicted those of Dodangeh and Yusuff (2011) and the new study concluded that it is necessary to develop other models to priotrize area of improvements and compare thier efficiency. Mariscal et al. (2012), in their model of assessing the safety culture in the nuclear indsutry, used RADAR matrix scores as a reference for prioritizing future actions. Ezzabadi, Saryazdi, and Mostafaeipour (2015) prioritized sub-criteria using a hybrid technique of AHP and Operations Research. The scholars selected experts and developed questionairres to compare criteria and sub-criteria.

Despite the extensive interest in performance excellence in healthcare, the literature shows that the Herat et al. (2012) model is the only model available to prioritize performance excellence areas for improvements in the healthcare setting. However, this model has some drawbacks. It does not include the stakeholders' preferences in decision-making, mainly relying on the opinions of experts and focus groups. Also, it does not consider the subjective judgment and uncertainty that exists in the process of decision-making. Consequently, there is a lack of a standard or a tool to prioritize areas of improvement in healthcare in the context of business excellence that can consider the perspective of different stakeholders such as patients, or the input of internal members as well as experts.

Several reports around the globe have emphasized the importance of engaging different stakeholders in quality improvement initiatives and incorporating their preferences to improve the healthcare efficiency and outcomes. In 2006, the annual WHO report highlighted the importance of determining who the relevant stakeholders are in healthcare and how they will be involved in quality improvement projects. Mühlbacher and Kaczynski (2016) linked healthcare improvement success to optimal decisions and considering different stakeholders' preferences. Vahdat, Hamzehgardeshi, Hessam, and Hamzehgardeshi (2014) illustrated the necessity of including patients' views of healthcare system improvements. At the same time, the literature shows a decent willingness from healthcare stakeholders to be involved in healthcare priority-setting. In a study conducted by Wiseman, Mooney, Berry, and Tang (2003) in Australia about public involvement in healthcare priority-setting, 80% of participants' supported the usage of public preferences in healthcare priority-setting. Litva et al. (2002) conducted a similar study in England; results showed a strong desire on the part of healthcare users to be involved in resource allocation and service areas decision making. Regardless of this trend of support from the public, the literature reveals that actual stakeholder involvement in healthcare decision making is limited

(Gallego, Taylor, & Brien, 2011) and that there is a scarcity of formal evaluation of their involvement (RAND, 2010).

Accordingly, with the increased pressure to achieve excellence in healthcare and the growing demand to meet government regulations, insurance company requirements, and accreditation body requirements and to provide effective patient services as well (Hochenedel & Kleiner, 2016), it is crucial to incorporate different stakeholders' preferences in improvement initiatives. Given the limited resources, time, and money in the healthcare context, it is impossible to implement all improvements simultaneously. Thus, there is a need to develop a framework to prioritize areas for improvement in the context of BEMs and consider different stakeholders' preferences when setting priorities.

Considering different stakeholders' perspectives in addition to expert judgments could yield more favorable and efficient outcomes. Nevertheless, it most probably would bring in conflict criteria due to the different interests and perspectives they would add to the process. Also, each healthcare system's particular characteristics differ from country to country and from one healthcare system to another (Kanji & Moura e Sá, 2003), and there are no universal criteria to prioritize healthcare problems (De Belvis et al., 2014). Thus, a framework is needed that can handle the special characteristics of the healthcare environment.

Table 2-9: Gap analysis

(Author, year)	Developed prioritizing model	Healthcare as targeted sector	Incorporated different stakeholders in improvement selection	Quantified the impact of uncertainty	Defined indicators
(Dodangeh & Yusuff, 2011)					
(Dodangeh et al., 2011)					
(Ezzabadi et al., 2015)					
(Herat et al., 2012)					
(Mariscal et al., 2012)					
(Aldarmaki & Elshennawy, 2018)					

Addressed in research
Identified as future work
Not addressed

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

The aim of research methodology in scientific research is to map out the process that will be applied to achieve the research objectives. It is a systematic planning for conducting the research. It details all research stages, from problem identification to framework development and validation. This chapter describes the research methodology which will be implemented in this dissertation in order to achieve the intended contribution in the area of study.

3.2 Research Methodology

The research originated with the concerns about the process following business performance assessment and actions taken after receiving feedback reports, especially about dealing with the system's weaknesses and defining improvement plans. Then, the focus was narrowed down to a specific industry, the healthcare system, as it has experienced a dramatic transformation in recent years and shows great interest in adopting a BEMs. Moreover, because the complexity of the healthcare system increases the impact of quality improvement decisions both horizontally and vertically, selecting the appropriate improvement plan is crucial. Review of a variety of peer-reviewed articles and technical reports revealing the drawbacks of famous business performance models to providing guidelines to prioritize quality improvement initiatives also contributed to the development of this study's focus.

Once the focus of the study was a bit sharper, an intensive review of literature on the general topic as well as to find the current efforts was conducted to identify any gaps within the context of the research area to identify the shortcomings and opportunities for contribution. Relevant literature about business excellence models popularly utilized by different industries was examined and in-depth analysis was carried out to determine the existing conceptual models to prioritize improvement opportunities in the context of business excellence models. Literature on business excellence and decision making in the healthcare system was also reviewed.

The literature review revealed a lack of reliability of the available models for use in healthcare. Thus, a research gap existed in the form of development of a novel framework to prioritize improvement initiatives in the context of business excellence in healthcare, one that can address various factors such as different stakeholders' perspectives, judgment uncertainty, and scalability. Consequently, the initial idea was refined to prioritize business excellence's improvement initiatives in the healthcare system and bridge the gap of the previous models by considering different healthcare stakeholders' preferences in quality improvement initiatives.

The next phase of methodology is to identify the initial framework architecture components. The preliminary framework architecture consists of several methods to achieve the targeted goal, including the Fuzzy Delphi method to define the prioritization criteria, Fuzzy logic to deal with human judgment and to prioritize the alternatives. After framework development, a case study will be conducted to validate the proposed framework. Conclusions, recommendations and future research will be presented depending on the results obtained. Figure 3-1 displays the in-depth process the research methodology has followed/will follow to tackle the research problem.

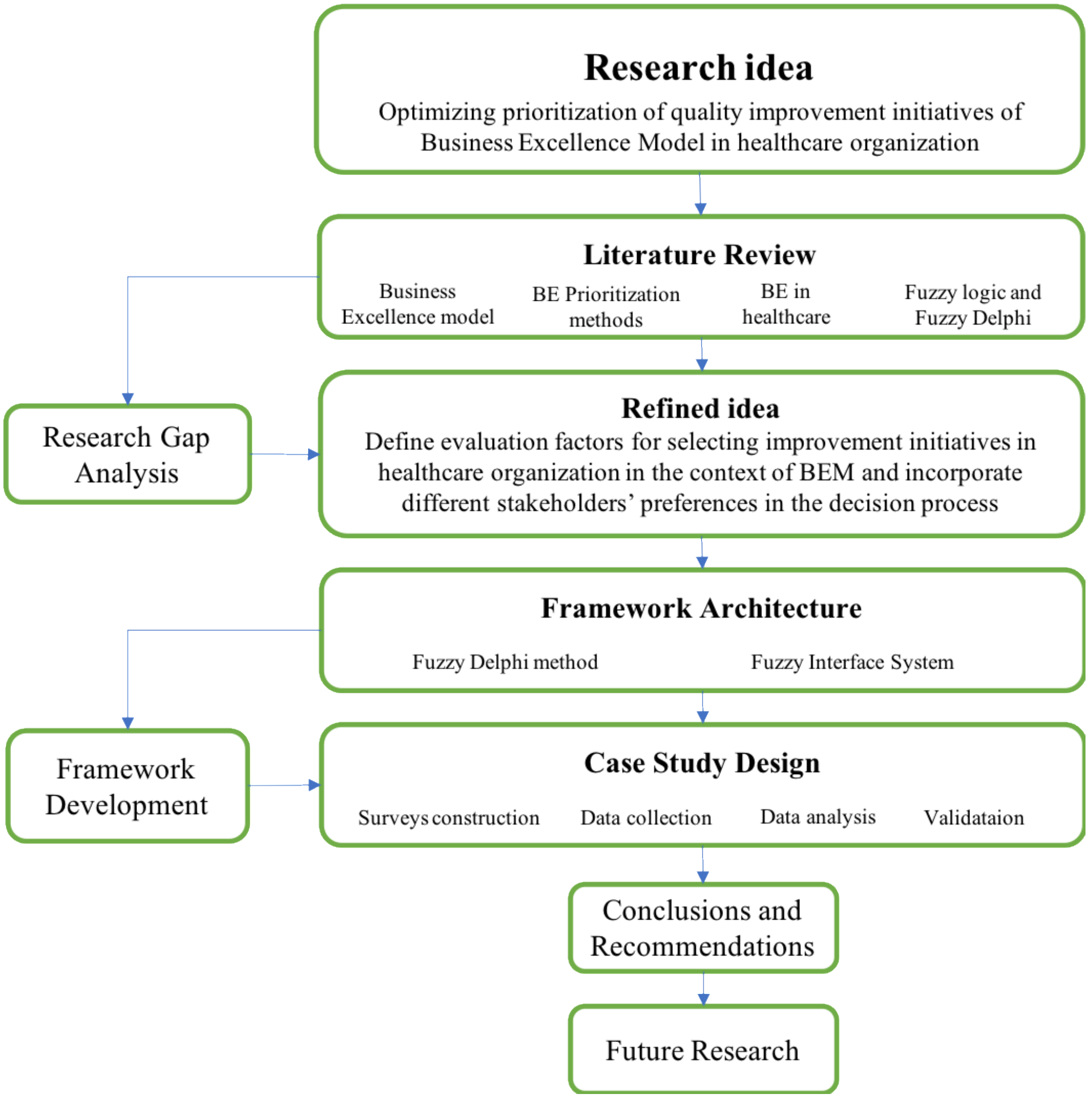


Figure 3-1: High level research methodology

3.3 Research idea

One of the main instructions in the Baldridge feedback's report is to:

> "Prioritize your opportunities for improvement. You can't do everything at once. Think about what's most important for your organization at this time and decide which things to work on first".

Moreover, EFQM feedback report shares the same view:

> "We have deliberately avoided making specific recommendations on potential approaches to secure improvement, this is outside the scope of our feedback. Neither the EFQM nor its Assessors will provide advice or recommendation for specific actions as result of this feedback, as we consider this your responsibility."

Improvement plans in any organization are restricted by several factors: time, budget, resources, and more. Hence, they can't all be implemented at once. Several scholars have expressed doubt about the ability of a performance excellence model to prioritize areas of improvement or opportunities for improvement in Baldridge. Nazemi (2010) concludes his research with

> "…the EFQM Excellence Model is appropriately structured to perform the identification of area for improvement, but the model does not offer any specific guidelines on improvement plan and result orientation."

Dodangeh et al. (2011) included in their research that

> "The current EFQM model has some drawbacks and problems which are not able to identify the priorities in Area for Improvement for organizations with limitations of time, budget and resources and cannot implement all the AFI, some standards or indexes and limitations should be defined for prioritizing and choosing the Area for Improvement".

Kirkham et al. (2014) express that

> "Due to the nature of EFQM and its assessment criteria, this method does not encourage organizations to objectively prioritize improvement activities. However, the adoption of this initiative may cause an organization to question its methods when reviewing the organizational performance in the self-assessment stage. It is evident that limited research is available in relation to their ability to influence an organization to use factual and structured methods towards the prioritization of improvement projects."

The former quotes were the basis for starting a scientific literature review to investigate and gain broader understanding to overcome this shortcoming and find a mechanism to optimize selection and prioritization of improvement initiatives in the context of business excellence. However, this is a very wide topic since various industries employ business excellence. Healthcare was identified as the target sector due to its recent massive transformation and new orientation, of which business excellence is a crucial part.

3.4 Literature review

The literature review was conducted to gain knowledge of the fundamental concepts related to different business excellence models and enable a comparison among them. The academic work related to project prioritization and selection, its definitions, and its financial impact, risk avoidance, and organizational competitiveness were also examined. The literature review shed light on the existing frameworks that have been developed to prioritize improvement projects in the context of Business Excellence Models in detail, explore the utilized approaches, targeted industry, entities involved in decision-making process, and compare the obtained results. In addition, the healthcare system and its new orientation to adopt innovative approaches to enhance the patient experience, raise market competitiveness, and increase the profit margin was reviewed. The literature presents the academic work done to illustrate the utilization of business excellence models in healthcare and the impact it has had on the system performance. Lastly, factors and challenges facing the decision-making process in healthcare were reviewed. Based on the intensive literature review and the various approaches scholars have developed to build frameworks, a gap analysis was performed that identified the need to find a mechanism to properly prioritize improvement initiatives of business excellence in healthcare organizations.

3.5 Gap analysis

The literature review of this study started with the simple questions: What are the approaches available to prioritize improvement initiatives in the context of BEMs? Is there any practical framework for use in the healthcare system? Four approaches were identified to prioritize improvement initiatives in the context of BEMs in different industries (Dodangeh et al., 2011; Dodangeh & Yusuff, 2011; Ezzabadi et al., 2015; Mariscal et al., 2012), with only one framework having been designed for use in a healthcare system (Herat et al., 2012). In addition, the literature review revealed that there has been a global shift to healthcare systems' emphasizing engaging different stakeholders in quality improvement initiatives and incorporating their preferences to improve the healthcare efficiency and outcomes. The literature also showed a decent amount of willingness from healthcare stakeholders to be involved in healthcare priority setting, however, actual stakeholder involvement being scarce. Hence, an extensive review of each framework to prioritize improvement initiatives in the context of BEMs was conducted to identify the used approaches and their validity to serve the current trend in the healthcare system to encompass different stakeholders' preferences in quality improvement initiatives decision making.

Based on the initial review, the next question became: Which stakeholders' preferences are incorporated in selecting the quality improvement initiatives in the context of BEMs in healthcare and how is this done? The literature showed that the available frameworks in general relied on managers and focus group inputs without considering different stakeholders' preferences, which could lead to failure and undesirable outcomes (Müller & Thoring, 2012).

The gap indicates that although different frameworks have been created to prioritize improvement initiatives in the context of BEMs, none encompass different stakeholders' preferences in selecting improvement initiatives, which might affect the accuracy and validity of improvement ranking. According to Mühlbacher and Kaczynski (2016), it essential to consider stakeholders' preferences in the decision-making process to improve healthcare efficiency. However, current research considers stakeholders involvement in decision making is limited.

(Gallego et al., 2011). Also, in quality improvement change it is important to determine the key stakeholders and how they are involved (WHO, 2006). Thus, there is a need to develop an appropriate framework that could help to prioritize improvement initiatives in the context of BEMs in the healthcare system which takes different stakeholders' preferences into account.

The next question is: How can we identify the indicators that are important when evaluating alternatives? The FDM is an appropriate approach because first, it performs content validity for the obtained indicators from the other industries and acquires additional indicators from subject matter experts, and second, it synthesizes experts' ratings to obtain the most critical indicators.

The next critical questions were: What method can deal with the uncertainty and ambiguity in human judgments? and Which methods can best prioritize quality improvement initiatives? The literature shows that Fuzzy logic is a robust method to deal with vagueness, use linguistics variables and convert subjective judgment into mathematical models. Fuzzy logic was selected as a potential approach since it satisfies all the properties necessary to build the framework, including being able to deal with subjective judgment, uses linguistic variables, has a statistical basis, and allows scalability. Table 3-1 illustrates a comparison among potential techniques, Fuzzy logic system is the most appropriate method to serve the objectives of this study.

Accordingly, a hybrid method including Fuzzy Delphi and Fuzzy Interface System has the potential to serve the objective of the research.

Table 3-1 Comparison between potential techniques

Properties \ Approaches	ANP/AHP	TOPSIS	Fuzzy Logic
Deals with conflict criteria			X
Simple calculation	X	X	X
Map inputs to output			
Deal with the uncertainty			X
Statistical basis	X	X	X
Subjective assessment			X

3.6 Case Study Design

After framework development, a case study will be conducted. The main purpose of the case study is to evaluate the framework's performance and validate its applicability. Using a case scenario approach is a suitable tool to test the framework performance. The selected case study should satisfy the following criteria:

- Should be within the research scope; in this research case study should be a facility in a healthcare system.
- Should adopt the Business Excellence Model for several years to avoid initial adoption drawbacks and ensure that the workforces are familiar with the used terminologies. Also, all case studies are preferred to adopt the same Business Excellence Model to facilitate the analysis and comparison phase.

.	Accessibility and availability of the data and the willingness to participate in the data collocation process

Although a single case research is valuable in a critical case, however, literature considering multiple case studies' findings are more compelling, and the overall study is more robust (Yin, 2013). Hence, this research intends to utilize multiple case studies' validation approaches by selecting two or three healthcare facilities to compare and analyze the outcomes of the case studies. The proposed framework will be tested in a United Arab Emirates hospital. Figure 3-2 illustrates the multiple case studies' approach that will be used in his research.

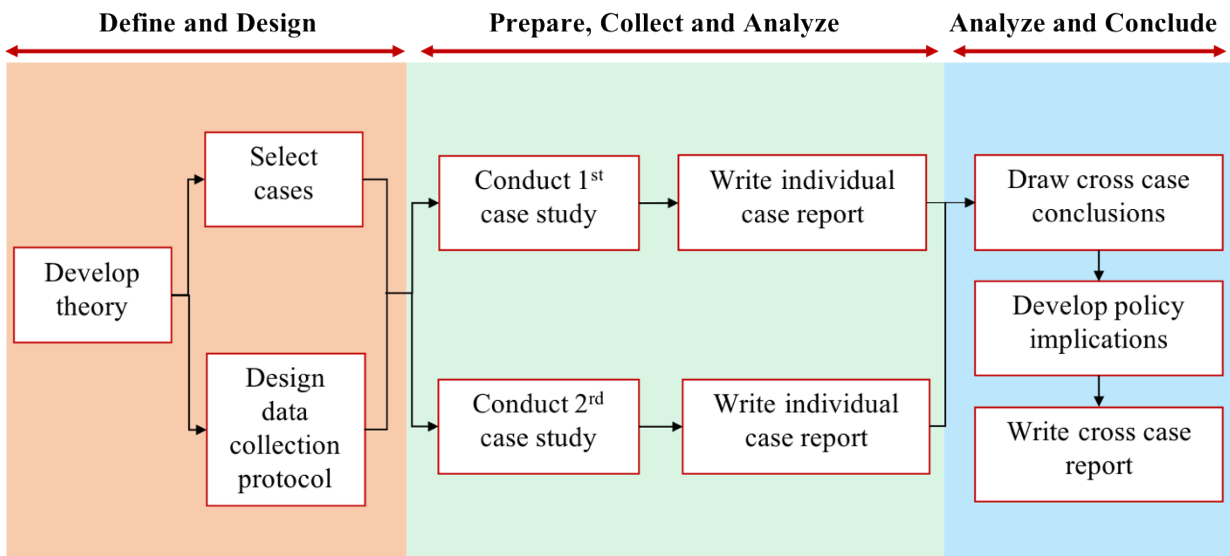


Figure 3-2: Case study method.

Adapted from: (Yin, 2013)

3.7 Conclusion

This research attempts the design of a novel framework to optimize prioritizing quality improvement initiatives in the context of a business excellence model in healthcare that takes into consideration different stakeholders' preferences, accounts for uncertainty, and select the most relevant criteria for healthcare improvement initiatives. If the proposed framework achieves an acceptable level of validity, it will enhance the decision-making process in healthcare, thereby optimizing healthcare resources, anticipating an improvement in next result of a BEMs scores. Moreover, it would provide future researchers with a fundamental framework in healthcare to further build upon.

3.8 Future research

As a first research attempt to identify relevant factors to prioritizing quality improvement initiatives in the context of a business excellence model in healthcare and engage different stakeholders in the selection process, the proposed framework will expose new opportunities to the subsequent researchers in the business excellence and healthcare domains. Potential future research could focus on identifying priority factors in other healthcare settings and test the existence of general patterns or divergence between different countries or healthcare systems.

3.9 Summary

In review, this chapter provided an overview of the proposed methodology for this study. First, it mapped out the research flow to achieve the stated objectives. Then it described the origins of the research idea and the intensive literature review conducted to identify the research gap. Subsequently, a detailed gap analysis was discussed to validate the need for the study within the context of a healthcare system. This chapter also shed light on the proposed preliminary framework and the technical details of each component. Moreover, it described the planned validation study and the method to be used to examine the framework's accuracy. Finally, potential future research areas were briefly discussed.

CHAPTER 4: FRAMEWORK DESIGN

4.1 Introduction

This chapter describes the constructed framework and expands on its components. First, an overview of the framework is outlined to clarify the relation between its components. Then the methods and procedures used in phase one to identify the key evaluation factors are described, including: determining potential factors through a review of the literature review and relevant research, the process of identifying the vital stakeholder groups, and finally using the FDM algorithm to capture experts' and vital stakeholders' perceptions. The second part of this chapter expands on the process of building the FIS scheme. First, it presents a justification of adopting the HFS vs. the standards logic system and describes the process of defining and rating the alternatives. Then it describes the architecture of FIS in detail, including the FIS subsystems, inputs, outputs and relation between the various subsystems. Also, the fuzzy rules and database development in the knowledge base is explored.

4.2 Framework outline

Based on the conducted literature review and gap analysis, a framework for prioritizing areas of improvement in a healthcare system in the context of the business excellence model was developed. The main objective of this research is to optimize prioritization of quality improvement initiatives of BEMs in a healthcare organization. Such an objective can be achieved through the framework proposed in Figure 4-1. This framework encompasses two different phases. The first phase aims at selection of the key evaluation factors; this process involves identifying potential evaluation factors and defining the vital stakeholders. The identified potential factors are then rated using FDM. The goal of the second phase is to prioritize improvement initiatives and obtain a priority index using a fuzzy interface system. The figure illustrates the relationship between the phases by showing the inputs and the targeted outputs. This framework considers different stakeholders' preferences in addition to expert knowledge and utilizes FDM to define the critical factors for the needs of an individual healthcare system, which makes this framework novel. The following section elaborates on each phase's objective, inputs, outputs, and tools used.

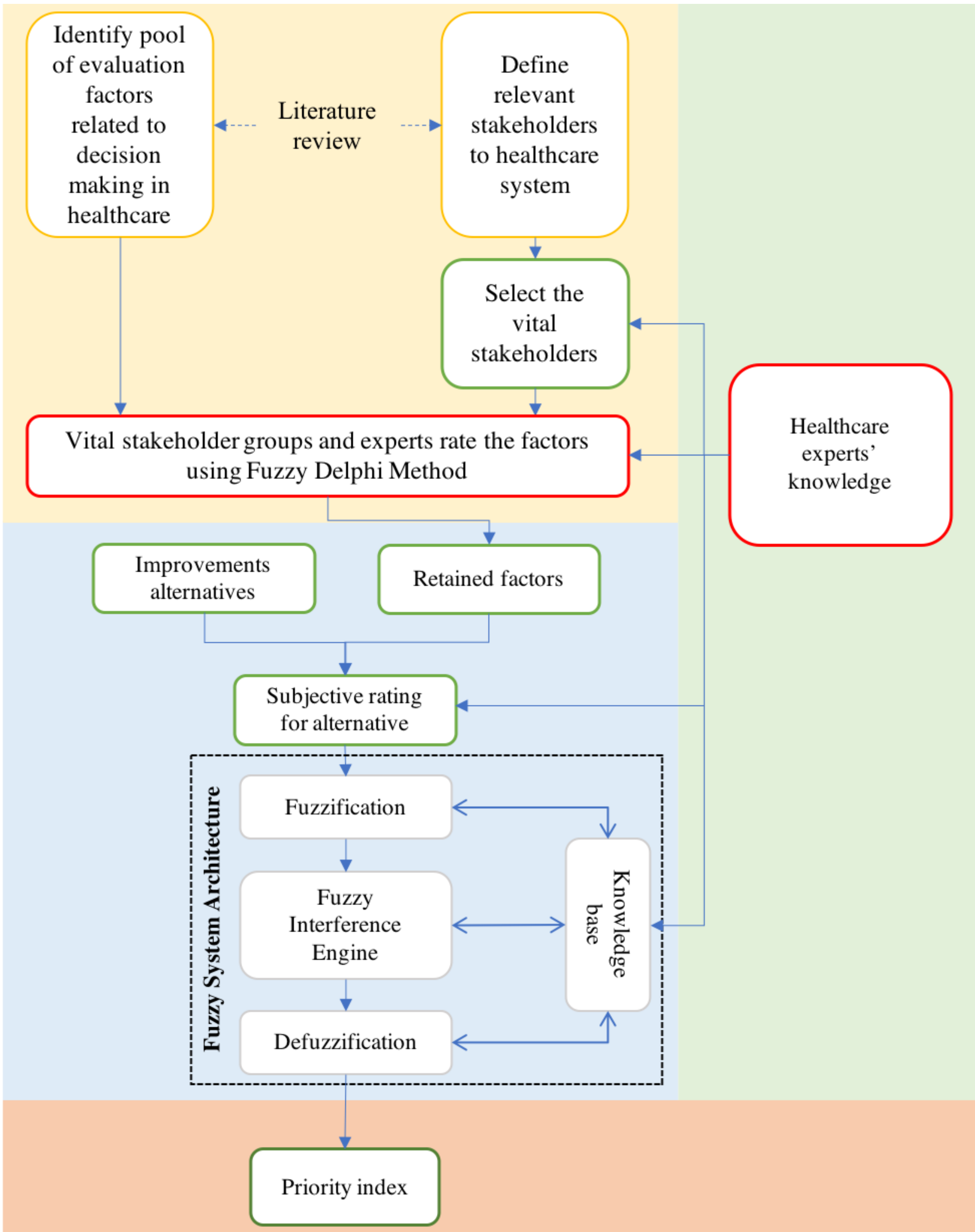


Figure 4-1: The proposed framework.

4.2.1 Phase 1: Selecting the key evaluation factors

There are various factors that can influence a healthcare system; however, a healthcare system's characteristics, preferences, and priorities differ from country to country and even from one healthcare system to another (Kanji & Moura e Sá, 2003) Also, according to the literature, there are no universal factors to prioritize healthcare problems (De Belvis et al., 2014). Hence, the framework permits selecting the best evaluation factors to cope with the characteristics and objectives of the healthcare system being studied.

The objective of this phase is to identify the most significant evaluation factors to consider in healthcare for selecting improvement projects using FDM. Prior to implementing FDM, a literature review was conducted to identify potential evaluation factors related to project improvement. Then FDM was utilized to obtain a weight for the evaluation factors using experts' knowledge and different stakeholders' inputs to select the most important ones. The FDM is mainly employed to handle the subjectivity of the human assessment. Figure 4-2 illustrates the FDM procedure.

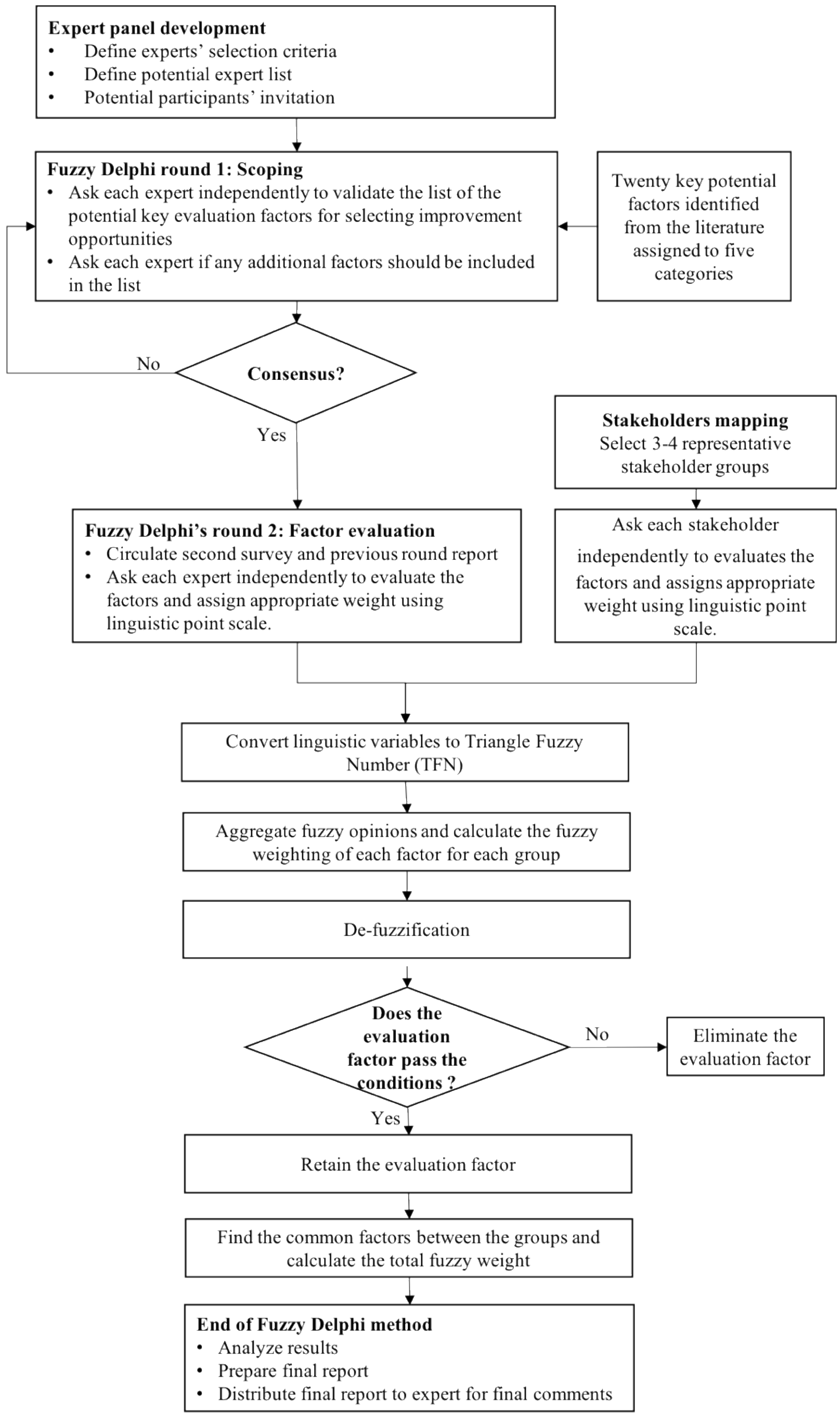


Figure 4-2: Procedure for selecting the key evaluation factors.

4.2.1.1 Determination of the improvement opportunities selection indicators

The identification of key evaluation factors for selecting improvement opportunities is the first step in the developed framework. According to the literature review there was no known study that identified such factors for the healthcare industry. Thus, the study surveyed the literature to establish a list of “potential key evaluation factors for selecting improvement opportunities” through compiling and investigating factors from other industries. Twenty potential key factors were identified. These factors were then assigned to one of five categories: operational feasibility, financial impact, social, strategical, and managerial, as shown Table 4-1.

Table 4-1: Categorization of related works for key evaluation factors for selecting improvement opportunities

		Strategical (D1)						Managerial (D2)					Operational feasibility (D3)				Financial impact (D4)			Social (D5)	
		Urgency	Impact/effectiveness	Importance/significance	Strategic alignment	Critical to quality	Competitive advantages	Top management commitment	Learning and growth potential	Risk	Legal implication	Ethical implication	Improvement duration/ Time	Resource and information availability	Cost	Ease of implementation	ROI	Cost reduction	Profit	Patients satisfaction	Health and safety
1	(Botta & Bahill, 2007)	X											X		X	X				X	X
2	(NACCHO, 2013)	X	X											X	X		X				
3	(Zhou, Lin, Wang, Zhou, & He, 2016)																			X	X
4	(Vinodh & Vikas, 2015)					X							X	X				X		X	
5	(F.-K. Wang, C.-H. Hsu, & G.-H. Tzeng, 2014)					X							X	X			X	X	X	X	
6	(Chakravorty, 2012)												X	X				X			X
7	(JúNIOR & ASANO, 2015)		X												X						X
8	(Saúl Torres, Nick, & Pedro Diaz, 2014)			X																	
9	(Henriksen & Christian Røstad, 2010)				X																
10	(Madjid, 2003)															X		X			X

		Strategical (D1)						Managerial (D2)					Operational feasibility (D3)				Financial impact (D4)			Social (D5)	
		Urgency	Impact/effectiveness	Importance/significance	Strategic alignment	Critical to quality	Competitive advantages	Top management commitment	Learning and growth potential	Risk	Legal implication	Ethical implication	Improvement duration/ Time	Resource and information availability	Cost	Ease of implementation	ROI	Cost reduction	Profit	Patients satisfaction	Health and safety
11	(Aghdaie, Zolfani, & Zavadskas, 2012)			X											X						
12	(Oztaysi, Onar, & Kahraman, 2016)									X					X						
13	(Worstell, 2002)																X				
14	(Tsai & Chen, 2013)		X	X	X		X			X				X		X			X		
15	(Helmstedt et al., 2016)		X												X						
16	(Nistorescu & Bogheanu, 2012)	X			X									X	X						
17	(Bolat, Çebi, Tekin Temur, & Otay, 2014)				X	X		X					X	X							
18	(Büyüközkan & Öztürkcan, 2010)								X	X					X				X	X	
19	(Cheng & Li, 2005)				X					X	X		X	X					X		X
20	(Habib, Khan, & Piracha, 2009)									X				X							X

4.2.1.2 Stakeholder identification

This step aims to identify the stakeholders relevant to improvement initiatives to enable their preferences to be incorporated into the decision making. The proposed framework attempts to incorporate different stakeholders' preference for priority setting by collecting the relative importance of the selected factors from the stakeholders' perspectives. The inclusion of stakeholders' perspectives is intended to enhance stakeholders' engagement and improve transparency throughout the decision process. The literature review defined a wide range of stakeholders for a healthcare system in general. Among those stakeholders, only the ones related to the improvement process will be included in the study. Thus, a stakeholder analysis was conducted to select the vital stakeholders. Kanji and Moura e Sá (2003) was used as a basis to identify all the possible stakeholders; nevertheless some stakeholders were merged in order to allow the list to be applicable to all healthcare systems, no matter what the structure, as shown in Table 4-2. Then a potential stakeholder list was sent to the top management, who were informed of the purpose of this step and asked to evaluate each group based on two criteria: stakeholder power (P) and necessity of stakeholder involvement (InV) (Appendix F). Stakeholder power represents the amount of influence the stakeholder has on shaping healthcare improvement and guiding its direction whereas necessity of stakeholder involvement denotes the level of importance of including the stakeholder's input in the study.

Table 4-2: Potential stakeholders' groups

Code initial	Stakeholder group
P&F	Patients & Families
LC	Local communities
CG	Commissioning groups
IN	Insurance companies and other third-party payers
HO	Other healthcare organizations
A&M	Administrators and managers
DR	Doctors/physicians
NR	Nurses
PA	Paramedical staff
GOV	Government
AUT	Authorities
ACC	Accreditation bodies
EC	Evaluation committees
OBS	Observers (future patients, media, etc.)
Sup	Suppliers

The participants used the linguistic variables: Very Low (VU), Low (L), Moderate (M), High (H), and Very High (VH) to rate each group. These linguistic variables were expressed as Triangular Fuzzy Numbers using the membership function in Table 4-3 and Figure 4-3.

Table 4-3: Linguistic variables and the corresponding fuzzy number used in stakeholders' analysis

Linguistic expressions	Fuzzy numbers
Very Low (L)	[0, 0, 0.25]
Low (L)	[0, 0.25, 0.5]
Moderate (M)	[0.25, 0.5, 0.75]
High (H)	[0.5, 0.75, 1]
Very High (VH)	[0.75, 1, 1]

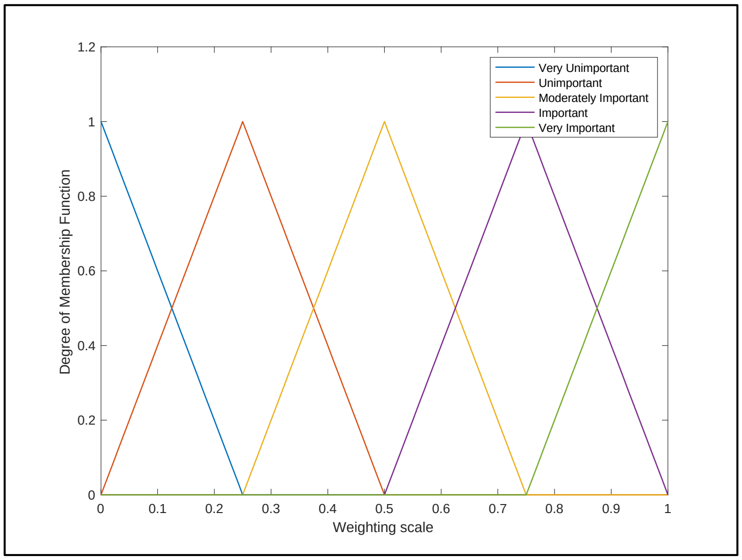


Figure 4-3: Membership function used in stakeholders' analysis.

The fuzzy number of the stakeholder power and necessity of stakeholder involvement criteria used to determine the power index of each stakeholder group (Zhou al., 2016) by using the appropriate fuzzy operators.

$$X = P \otimes InV \tag{29}$$

The next step was to aggregate experts' fuzzy opinions and calculate the fuzzy weighting for the criteria (necessity of involvement and power criteria) and stakeholders' power using the following equations.

$$P_z = (\frac{1}{n}\sum P_{iz} ,\frac{1}{n}\sum P_{iz}\ \frac{1}{n}\sum P_{iz}) \tag{30}$$

$$InV_z = (\frac{1}{n}\sum InV_{iz} ,\frac{1}{n}\sum InV_{iz}\ \frac{1}{n}\sum InV_{iz}) \tag{31}$$

$$X_z = (\frac{1}{n}\sum X_{iz} ,\frac{1}{n}\sum X_{iz}\ \frac{1}{n}\sum X_{iz}) \tag{32}$$

Where *i* denotes the participants (i =1, 2... n) and *j* represents the stakeholder (z = 1, 2 … k)

The previous fuzzy number was then converted to real number using the following equations.

$$P_T = \frac{P_1 + P_2 + P_3}{3} \tag{33}$$

$$InV_T = \frac{InV_1 + Inv_2 + InV_3}{3} \tag{34}$$

$$X_T = \frac{X_1 + X_2 + X_3}{3} \tag{35}$$

Then a power/ necessity of involvement matrix was plotted to find the key players among the stakeholders. The key players, that is, those with the highest power index only, were included in the study to limit the collected data. Figure *4-4* Illustrates the general scheme for the stakeholders' analysis.

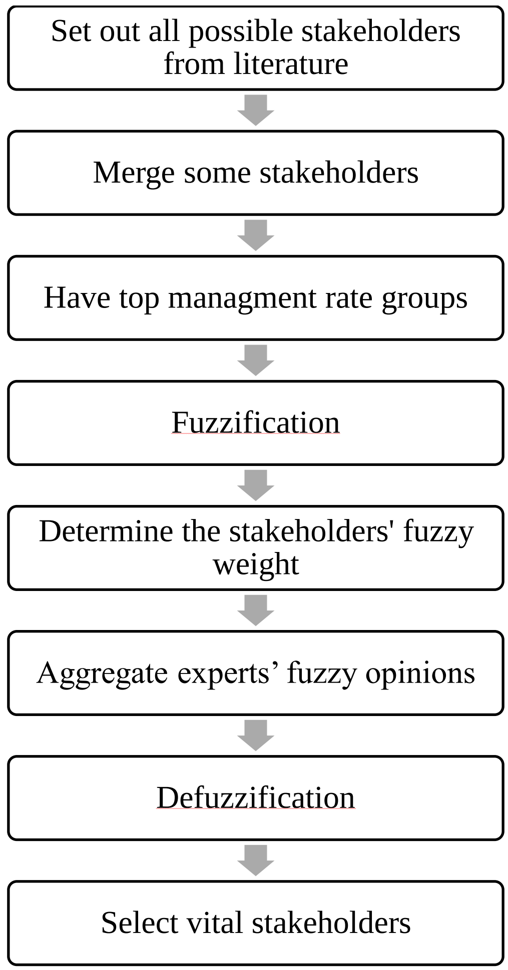


Figure 4-4: Stakeholders' analysis scheme.

4.2.1.3 Fuzzy Delphi method

The FDM algorithm in this study included the following steps:

Step 1: After the potential evaluation factors for selecting improvement opportunities were identified, the criteria for the selection of experts were defined. Specifically, the expert should: a) be a current employee in a healthcare related facility; b) have more than five years' experience in healthcare industry and c) have a background in quality management. Then the selected experts were invited to review and validate the pre-defined list of variables. Moreover, the experts were asked to suggest any possible missing variables. Step 1 had the potential to be repeated if major changes were recommended (English and Arabic versions of the surveys in Appendix G).

Step 2: The selected experts' opinions were collected through fuzzy questionnaires, that is, a committee of *n* experts evaluated *m* criteria and assigned an appropriate weight to each factor based on its importance. The experts selected linguistic terms for each factor. A 3, 5, 7, or 9 linguistic point scale can be used for the evaluation, as the number of linguistic scale levels must be odd. Higher linguistics scales can provide more accurate data (Kamarulzaman, Jomhari, Raus, & Yusoff, 2015). In this research, five fuzzy sets were utilized in this study in the form of linguistic weighting variables, including: Very Unimportant (VU), Unimportant (U), Moderately Important (MI), Important (I), and Very Important (VI).

Step 3: Each linguistic term was converted to a Fuzzy Number, using the triangle fuzzy membership function, the most commonly used membership function in FDM. The triangle fuzzy number of each linguistic term can be presented as follows:

$$A_{ij} = (a_{ij}, b_{ij}, c_{ij})$$

Where *i* is an individual expert's notation (i =1, 2... n) and *j* represents the evaluation factor (j = 1, 2 … m)

Figure 4-5 illustrates the membership function for importance weights and Table 4-4 presents the linguistic variables and their corresponding fuzzy number.

Table 4-4: Importance weights linguistic variables and fuzzy numbers.

Linguistic expressions	**Fuzzy numbers**
Very Unimportant (VU)	[0, 0, 0.25]
Unimportant (U)	[0, 0.25, 0.5]
Moderately Important (MI)	[0.25, 0.5, 0.75]
Important (I)	[0.5, 0.75, 1]
Very Important (VI)	[0.75, 1, 1]

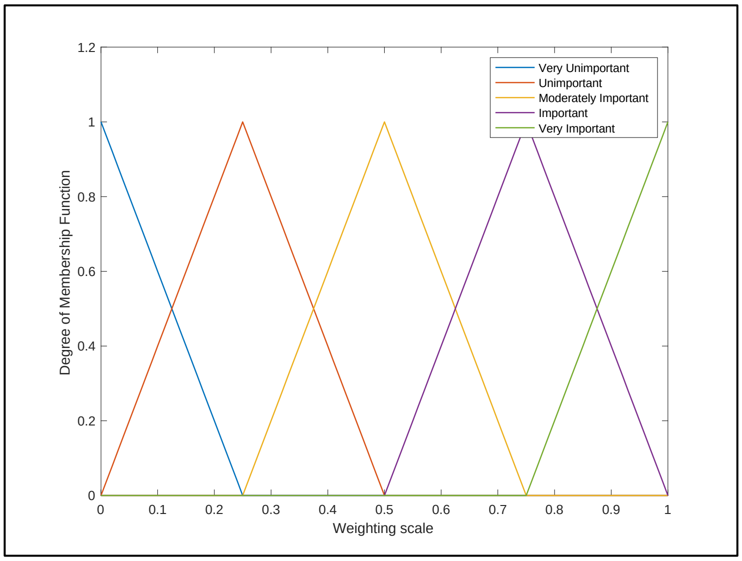


Figure 4-5: Importance weights membership function for the evaluation factors

Step 4: The experts' fuzzy opinions were aggregated, and the fuzzy weighting of each criteria was calculated using the equation below.

$$W_j = (a_j, b_j, c_j), \quad j = 1,2,..., m \qquad (36)$$

There are various methods to aggregate the experts' opinions. The simplest is using the fuzzy average (Tahriri et al., 2014), which was used in this research, and is depicted in the following equation:

$$W_j = (\frac{1}{n}\sum a_{ij} \,, \frac{1}{n}\sum b_{ij} \; \frac{1}{n}\sum c_{ij}) \quad (37)$$

Other researchers (Gil-Lafuente et al., 2014; Habibi et al., 2015; Wu & Fang, 2011) have suggested using a geometric mean instead of the fuzzy average; thus, fuzzy weighting becomes

$$W_j = (\sqrt[n]{\prod_{i=1}^{n} a_{ij}} \,, \sqrt[n]{\prod_{i=1}^{n} b_{ij}} \,, \sqrt[n]{\prod_{i=1}^{n} c_{ij}}) \quad (38)$$

Other sources use an aggregation method based on experimental methods to calculate the fuzzy weighting. For example, Hsu et al. (2010) utilized the following formula for a set of triangle fuzzy numbers:

$$W_j = \left(min_i\left(a_{ij}\right), \frac{1}{n}\sum b_{ij} \,, min_i\left(c_{ij}\right)\right) \quad (39)$$

While Kuo and Chen (2008) applied the following to aggregate the experts' opinions:

$$W_j = (min_i\left(a_{ij}\right), \sqrt[n]{\prod_{i=1}^{n} b_{ij}} \,, min_i\left(c_{ij}\right) \quad (40)$$

<u>Step 5:</u> The fuzzy weight number was converted to a crisp, real number for each criterion. This method is known as Defuzzification. There are numerous methods used to achieve defuzzification, such as Center Of Gravity (COG), mean of maxima, and center of area (Litva et al.), but the simplest method is to calculate the average triangular fuzzy number (Habibi et al., 2015; Hsu et al., 2010; Wu & Fang, 2011), which was used, as follows:

$$W_T = \frac{a_j + b_j + c_j}{3} \quad (41)$$

Step 6: The level of expert consensus was measured to determine whether each factor should be retained or rejected. In order for a criterion to be retained, it had to meet three conditions(Karim, Ahmad, & Osman, 2017) :

1- A threshold value (d) of less than or equal to 0.2. The threshold value measures the distance (deviation) between the participants fuzzy number and the average fuzzy number. The goal is to achieve a reasonably small value as a proof of expert consensus. The d-value is calculated using the following formula (Cheng & Lin, 2002).

$$d = \sqrt{\frac{1}{3}\ (m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2} \qquad (42)$$

2- Group agreement of greater than 60 %. This value represents the frequency of accepted values and an indication of reaching agreement. Group agreement can be calculated as follows.

$$\%\ \text{of Group agreement} = \frac{\#\ \text{of participants inputs with thershold value} \leq 0.2}{\text{Total number of participants}} \qquad (43)$$

3- An average fuzzy number of greater than 0.65. According to Chia-Wei and Cheng-Ta (2010) a factor with a high average fuzzy number indicates a high level of importance. In this study the average fuzzy number of each criterion compared to alpha-cut of 0.65, which reflected that only factors with a large membership grade should be included.

Step 7: The evaluation factors which were common among the groups were found. If a factor was common among at least two groups, the evaluation factor was considered a vital factor. Then the total fuzzy weight for each factor was calculated. The goal of this step was to integrate the opinion of all of the stakeholder groups. However, according to Cungen, Zaiyue, and Shang (2009) fuzzy numbers describe situations more realistically than just a single number, thus the total weight was calculated again in fuzzy number form, as follows:

$$W_{Total} = \frac{1}{K}\left(\sum_{z=1}^{k} W_{1z}\ , \sum_{z=0}^{k} W_{2z}\ , \sum_{z=0}^{k} W_{3z}\right) \qquad (44)$$

Where k is the number of groups; including the experts; that participated in the factor selection process.

4.2.1.4 Survey translation process

The goal of the translation process was to have equivalent concept surveys for different languages. Equivalence among the different versions of a survey is conceptual and cross cultural rather than linguistic. Due to the nature of the study in involving different stakeholders and its being implemented in the Middle East, an appropriate translation process was essential to ensure the consistency between the English and Arabic versions of the instruments.

The forward-translations and back-translations is a well-established approach to testing the quality and accuracy of the instruments. According to WHO (2018) the implementation of this approach includes the following steps:

1. In forward translation step, the English version of the instrument was submitted to a professional translator and he/she was familiar with the terminology used in the instrument. The mother tongue of the translator should be the target group's primary language; in our case is Arabic.
2. In expert review step, a specialist in the area of the study and bilingual in both languages reviews the instrument to resolve any problems with inadequate

concepts due to the translation. This step will result in a complete Arabic version of the survey.

3. In back-translation step, an independent translator and native speaker of English translates the instrument produced from the last step back into English. The aim was to compare the result with the original instrument to evaluate the equivalence of both.
4. In pre-testing and final version step, the instrument was tested on a sample with a minimum of ten responses. An additional section was added to the instrument asking the participants for their feedback about the instrument's language, unacceptable expressions, areas lacking clarity. Based on the feedback, a final version of the instrument is produced

4.2.2 Phase 2: Fuzzy Interface System

The second phase in the framework attempts to prioritize improvement initiatives, mainly using the Fuzzy Interface System. Mühlbacher and Kaczynski (2016) point out that most MCDM research of healthcare systems does not assess the impact of uncertainty. The developed framework attempts to resolve the problem of uncertainty and vagueness of preferences in practice utilizing the fuzzy logic system.

Hierarchical Fuzzy Systems (HFSs) are utilized in the implementation of the fuzzy interface system, as HFSs reduce the total number of fuzzy rules needed. For instance, if a standard fuzzy system has six crisp variables, and each variable includes five fuzzy sets, the total number of fuzzy rules equal 5^6 = 15,626 rules whereas if an HFS has six crisp variables, with five subsystems each including two inputs, the total number of fuzzy rules equals only $5^2 * 5 = 125$ rules. Thus, HFS was utilized in this study to reduce the number of rules associated with the evaluation factors. The HFS also allows finding intermediate values for the subsystems, which helps to determine the relationship between the main fuzzy system and the fuzzy subsystems, as well as the relationship between variables in the same subsystem. Figure 4-6 demonstrates the different between Standard and Hierarchical Fuzzy System.

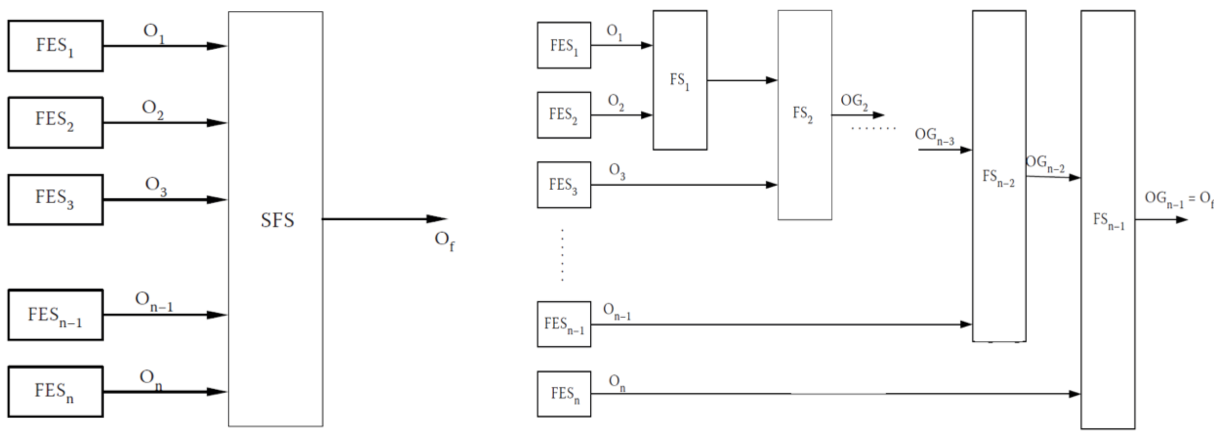


Figure 4-6: Standard vs. Hierarchical Fuzzy System.

Adapted from (Aly & Vrana, 2007)

In this research, utilizing HFS appeared to be the more reliable approach as it reduces the total number of the fuzzy rules. This reduction simplifies the model and its calculations and creates intermediates indices.

Figure 4-7 illustrates the built HFS for this study. The hierarchical system was divided into three layers. The “Inputs Layer” represents the selected evaluation factors that supply the inputs to the model. The “Dimension layer” deals with the evaluation factors that produce outputs that represent the framework dimensions. The “Intermediate layer” is a level that attempts to combine the dimension layer’s outputs with a reduction to two outputs only. The “Integration layer” aggregates the values from the “Intermediate layer” and finds a priority index for each alternative. It is worthwhile to say that a Mamdani fuzzy inference system was utilized in this research due to its wide acceptance, suitability to human input and intuitiveness.

The following sub-sections details the construction of the FIS.

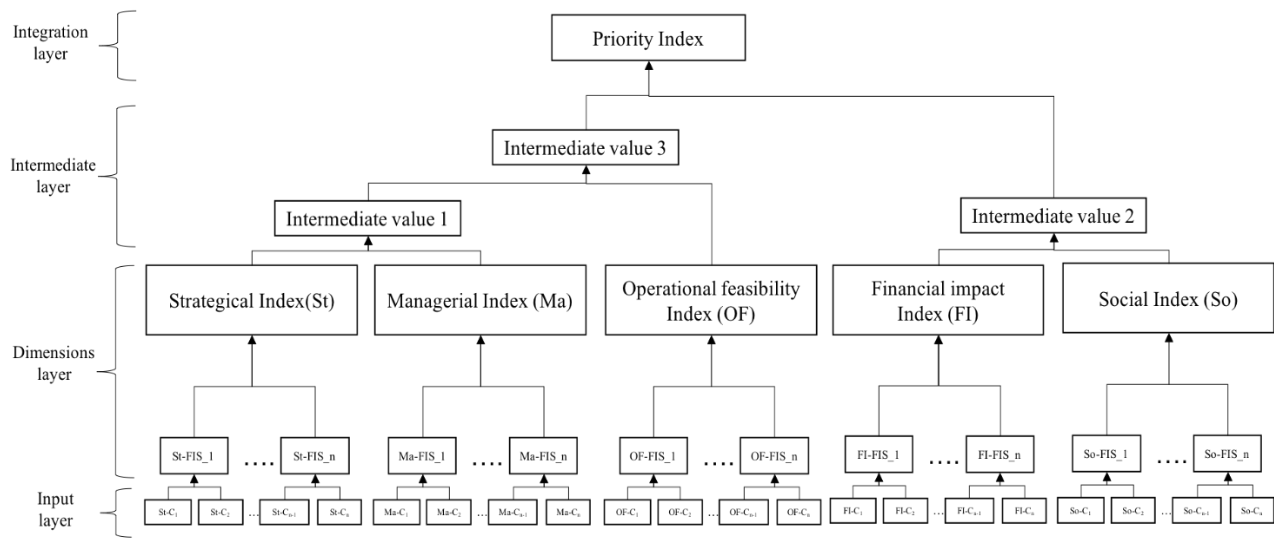


Figure 4-7: The proposed Hierarchical Fuzzy System

4.2.2.1 Fuzzy System Architecture

The study proposes a four-layer HFS. Each layer consists of several FIS, where the number of FIS will vary depending upon the selection of the evaluation factors from the FDM phase. Figure 4-9 presents the proposed model’s architecture. The figure assumes that all of the evaluation factors were selected and included. However, in testing the model with a real case study, only the significations factors were included and accordingly, the number of fuzzy systems in the other layers were reduced. All the FIS in the model include a fuzzifier, a fuzzy inference engine, a knowledge base, and a defuzzifier, as shown in Figure 4-8. However, the FIS in each layer has different inputs, outputs, fuzzy logic rules and membership functions.

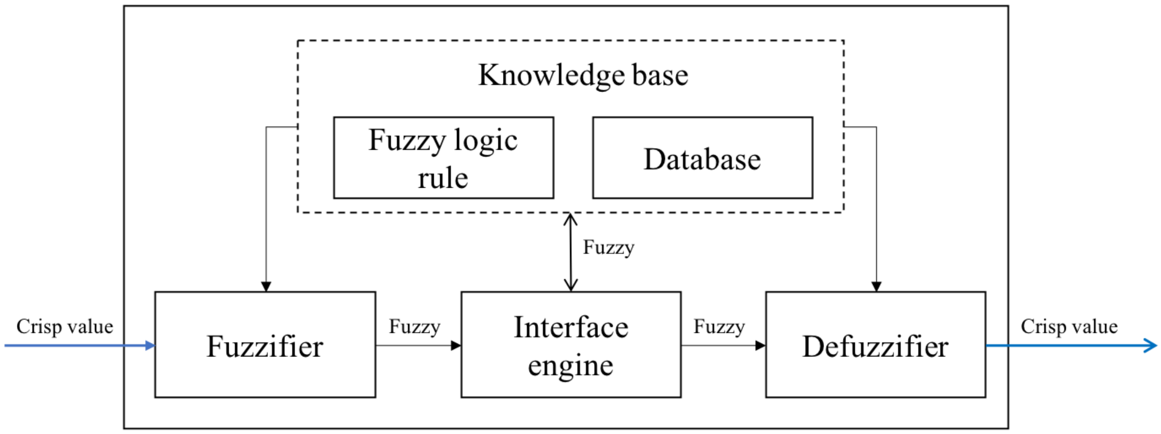


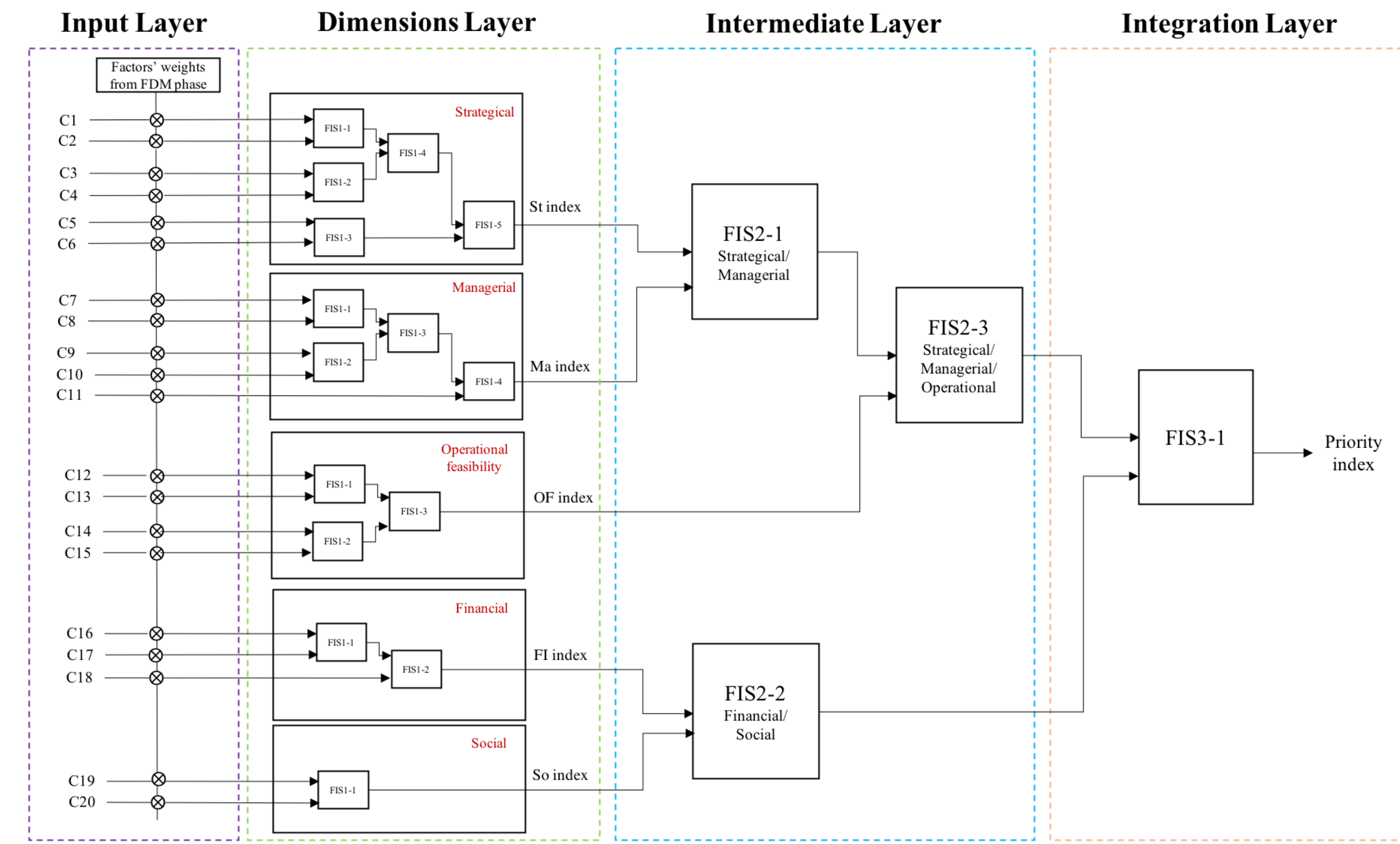
Figure 4-8: The model FIS subsystem

The FISs in the Dimensions layer designed to determine the framework's dimensions index by aggregating the inputs values related to the relative weight of the evaluation factors and crisp values of improvement ratings. The inputs were characterized by five fuzzy sets:" Very Low", "Low", "Moderate", "High", and "Very High". A trapezoidal function was used to assess the membership function degree on the interval [0,1]. The fuzzy logic rule in each FIS has 25 rules. The output index was assessed with a triangular function of [0,1] interval.

The FISs in the Intermediate layer generate intermediate values to contribute to the final indicator. Thus, the inputs of this layer are the output of the previous and utilize triangle membership functions of five fuzzy sets for the inputs and outputs, represented by five trapezoidal membership functions:" Very Low", "Low", "Moderate", "High", and "Very High."

These assess on the interval [0,1]. There are 25 fuzzy rules in each FIS in the Intermediate layer.

The final layer, the “Integration Layer”, combines all of the previous indicators to generate a priority index for each alternative. The input of this layer is the output of the previous layer, which is the intermediate variables while the output is a priority index, represented by three membership functions: “Weakly Preferred”, “Moderately Preferred”, and “Strongly Preferred”. It is assessed on a trapezoidal membership function with the interval [0, 1]. The last FIS on the model has 25 logical rules.



* Note: number of inputs will vary depending on the evaluation factors identified from the FDM phase; consequently, the number of FIS blocks will vary.

Figure 4-9: The proposed model architecture

4.2.2.2 Alternatives definition and rating

This section defines the alternatives to be prioritized by the model. Conventional models would require defining specific improvement projects as alternatives when implementing in a specific hospital, which this framework also requires. However, the main objective of this model is to prioritize improvement projects in the context of BEMs since improvement project performance depends on defining high priority area of improvements. In this respect, alternatives in this study will be BEM sub-criteria. BEM sub-criteria are a common platform in most hospitals, which enables a comparison among different hospitals' interests with regards to improvements. In this research EFQM sub-criteria were used as alternatives since all of the hospitals in the UAE follow the EFQM model (Appendix A).

In addition to the criteria required to select experts in the previous phase, the expert for this phase must be EFQM-certified in order to be familiar with the sub-criteria. Survey 2 (Appendix H) was sent for experts to rate the expected performance of each EFQM sub-criteria with respect to the critical evaluation factors using the linguistic terms:

1- Very Low (VL) (0%): expected performance is very low with respect to the factor as there is no direct relation between the sub-criteria and the evaluation factor.
2- Low (L) (25%): expected performance is low with respect to the factor as there is a limited relationship between the sub-criteria and the evaluation factor.
3- Moderate (M) (50%): expected performance is moderate with respect to the factor as there is a reasonable relationship between the sub-criteria and the evaluation factor.

4- High (H) (75%): expected performance is very high with respect to the factor as there is remarkable relationship between the sub-criteria and the evaluation factor.

5- Very High (VH) (100%): expected performance is very high with respect to the factor as there is substantial relationship between the sub-criteria and the evaluation factor.

The Fuzzy set values and membership function for the alternatives' expected performance were defined based on the RADAR matrix scoring (Ezzabadi et al., 2015) shown in Table 4-5 and Figure 4-10. Experts' rating were converted to fuzzy numbers and aggregated, and then the fuzzy average numbers were calculated. The fuzzy numbers for each alternative's expected performance with respect to a factor were then multiplied by the relative importance of that factor and defuzzified. The multiplication process causes a range reduction of the alternative's expected performance [0,100]. Consequently, the results did not satisfy the designed rules, resulting in inadequacies in the system's precision. Hence, the outputs crisp values were normalized to resolve this issue using unity-based normalization equation below.

$$X_n = \frac{X - X_{min}}{X_{max} - X_{min}} \qquad (45)$$

Table 4-5: Linguistic variables and Fuzzy set values for the alternatives' expected performance

Linguistic expressions	**Fuzzy numbers**
Very Low (VL)	[0, 0, 15]
Low (L)	[10, 25, 40]
Moderate (M)	[35, 50, 65]
High (H)	[60, 75, 90]
Very High (H)	[85, 100, 100]

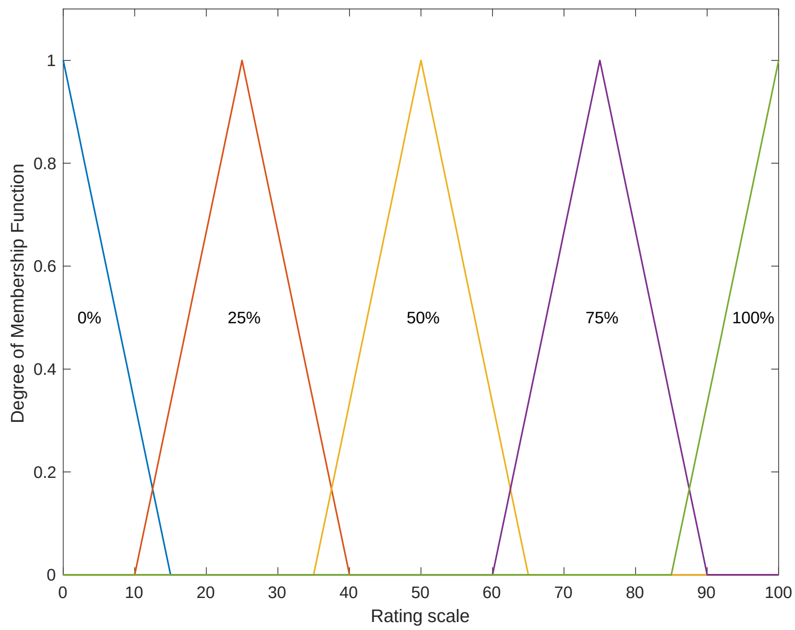


Figure 4-10: TFN of alternatives expected performance

4.2.2.3 Data Construction

The database consists of the system's fuzzy sets and their membership function. The database supplies the fuzzifier and De-fuzzifier with all the needed information about the membership function of the inputs and outputs. There are numerous approaches to acquire expert knowledge such as point estimation, reverse rating, direct rating, and indirect interval estimation (Sancho-Royo & Verdegay, 1999). In this study the indirect interval estimation approach was employed since it does not require any prior knowledge about membership function or fuzzy logic. The approach asks multiple experts to identify intervals that can define the linguistics terms.

Constructing the membership functions and the fuzzy sets involves surveying the subject matter-experts (Appendix I). The survey aims to quantify the linguistic terms by defining a numerical interval for each factor and then obtain expert consensus by performing an intersection for intervals and allocating the ambiguous areas. The output of the survey basically is multiple intervals for each factor, which are used to build its membership function by finding the subset intervals and the ambiguous areas.

In this study, trapezoidal and triangular membership functions are utilized in the entire fuzzy interface system due to their simplicity and the limitation of the available data. The trapezoidal membership function is defined in Eq. (46), if b = c the result is a triangular fuzzy number.

$$\mu(x) = \begin{cases} 0 & x<a \\ \frac{1}{b-a}(x-a) & a \leq x \leq b \\ 1 & b \leq x \leq c \\ \frac{1}{c-d}(x-d) & c \leq x \leq d \\ 0 & x>d \end{cases} \tag{46}$$

The trapezoidal and triangular membership function are defined by three characteristics: a core, a support, and a boundary. The core is the region where the function has a full and complete function ($\mu(x) = 1$). The support region is nonzero membership in the universe space ($\mu(x) > 0$). The boundary is the nonzero membership that doesn't have a full membership function ($0 < \mu(x) < 1$). Figure 4-11 demonstrates the membership function's regions.

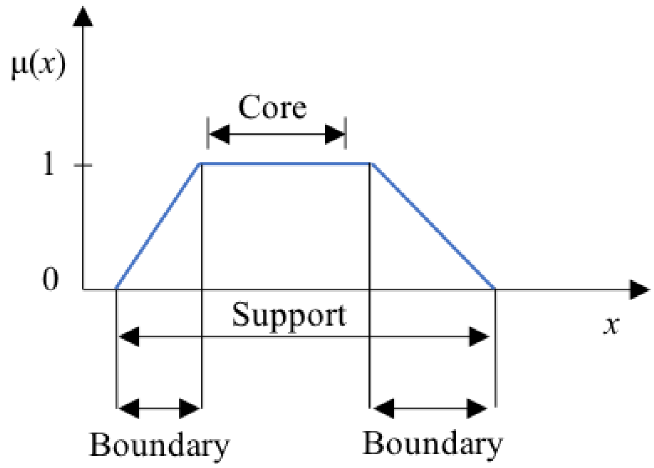


Figure 4-11: Regions of membership function

Based on the expert knowledge acquisition survey, trapezoidal membership functions with five fuzzy sets were built and applied to the FIS system's inputs in the input layer.

The output membership function for the "Dimensions Layer" (and the Intermediate Layer's input) is the standard membership function (Figure.4-12). The linguistic variables for the output include: Very Low (VL), Low (L), Moderate (M), High (H), and Very High (VH).

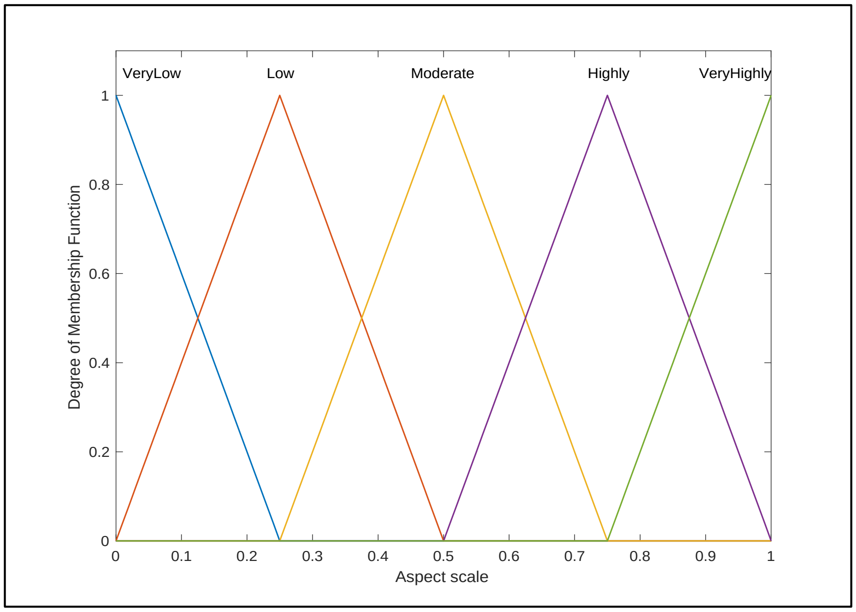


Figure.4-12 : Membership function for dimensions layer's outputs

It is a triangular function with values peaking at 1, and its boundaries overlap the adjacent classes perfectly. This reveals that the membership function always acquires data from two classes. At any given point on the standard triangle membership function, the membership degree equals 1 due to classes overlapping. The equivalent fuzzy numbers for those variables are presented in Table 4-6.

Table 4-6: The linguistic terms and fuzzy numbers for dimensions layer's outputs.

Linguistic expressions	**Fuzzy numbers**
Very Low (VL)	[0, 0, 0.25]
Low (L)	[0, 0.25, 0.5]
Moderate (M)	[0.25, 0.5, 0.75]
High (H)	[0.5, 0.75, 1]
Very High (VH)	[0.75, 1, 1]

In the “Intermediate Layer”, the same tringle membership function with five fuzzy sets used in dimensions layer is used for FIS outputs.

In the “Integration Layer”, the membership functions of the five fuzzy sets, which is the output of the Intermediate Layer, is considered as input and membership functions of three fuzzy sets were the FIS’s output. The linguistic variables of the outputs are: Weakly Preferred (WP), Moderately Preferred (MP), and Strongly Preferred. The membership function and fuzzy set of the integration layer were also constructed from acquiring experts’ knowledge (Appendix I).

4.2.2.4 Fuzzy rules construction

In order to design the fuzzy rule, evaluation factors were arranged into two categories using two types of quality characteristics: smaller is better and larger is better, as shown in Table 4-7.

Table 4-7: Evaluation factors based on the types of quality characteristics

Smaller is better	Larger is better
1- Improvement duration/Time 2- Cost 3- Risk 4- Legal implications 5- Ethical implications	1- Resource and information availability 2- ROI 3- Ease of implementation 4- Cost reduction 5- Profit 6- Patients satisfaction 7- Health and safety 8- Urgency 9- Impact/effectiveness 10- Importance/significant 11- Strategic alignment 12- Critical to quality 13- Competitive advantages 14- Top management commitment 15- Learning and growth potential

The FIS systems are multi-input and single output; thus a Fuzzy Rule Based System (FRBS) is used in the format of IF X=A and Y= B then Z=C. The rules were designed using the average of the two inputs. For example, if a sub-criterion has “High” expected performance from a cost perspective and “Low” expected performance from a time perspective, then the FIS output is “Moderate.”

The inputs of the “Dimensions layer” are the different evaluation factors, and as indicated above, each factor belongs to one of the two types of quality characteristics. Thus, three matrices should be developed: in cases where both inputs are from “the smaller the better”, where both inputs are from “the larger the better”, or in cases where the inputs are from different groups, one from “the smaller the better” and the other from “the larger the better”. However, to be consistent and to use the same fuzzy rules, complements for all the evaluation factors in “the smaller the better" group are found (A= (1-A')). In cases where both variables are from "the smaller the better" group, complements of both are found.

The rules were constructed (Table 4-8) based on the average of both inputs. If the average was found to be between two variables, the larger value was selected (the larger the better)

Table 4-8: Fuzzy rules matrix in level 1

Input 1	Input 2				
	VL	L	M	H	VH
VL	VL	L	L	M	M
L	L	L	M	M	H
M	L	M	M	H	H
H	M	M	H	H	VH
VH	M	H	H	VH	VH

In the Intermediate layer, a fuzzy rules matrix was designed to aggregate the framework's dimensions, and sub-criteria with higher value of dimensions indices (operational feasibility, financial impact, social, strategical, Managerial) were preferred. The Integration Layer aims to aggregate the inputs of the previous level to rank the alternatives, the inputs to the layer are VL, L, M, H, and VH, but the outputs are Weakly Preferred (WP), Moderately Preferred (MP), Strongly Preferred. The goal is to select an improvement project that has the highest expected performance from each dimension. Thus, the following conditions were considered to construct the rules for the intermediate layer and the integration layer:

- Any improvement scoring VL in any dimension was categorized as weakly preferred
- Any improvement scoring L in more than half of the dimensions was categorized as weakly preferred

- The improvement should score at least H or VH in half of the dimensions and a minimum score of M in the rest of the dimensions to be strongly preferred.

To satisfy the previous conditions, the fuzzy rules matrices in Table 4-9 and Table 4-10 were constructed for the intermediate layer and the integration layer, respectively.

Table 4-9: Fuzzy rules matrix for the intermediate layer

Input 1	Input 2				
	VL	L	M	H	VH
VL	VL	VL	VL	VL	VL
L	VL	L	M	M	H
M	VL	M	M	H	H
H	VL	M	H	H	VH
VH	VL	H	H	VH	VH

Table 4-10: Fuzzy rules matrix for the integration layer

Input 1		Input 2			
	VL	L	M	H	VH
VL	WP	WP	WP	WP	WP
L	WP	WP	WP	WP	WP
M	WP	WP	MP	MP	MP
H	WP	WP	MP	SP	SP
VH	WP	WP	MP	SP	SP

4.2.2.5 Fuzzification

The fuzzifier converts the crisp value into fuzzy values based on fuzzy rules and the defined membership function obtained from the database by determining the degree of belonging to the membership function. In the FIS, the input to the first fuzzifiers in the input layer are the alternatives rating in respect to each evaluation factor, whereas the input for the other layers is the output value of the previous FIS. The output of all fuzzifiers is a membership degree, which is used to test the degree of satisfying each rule.

4.2.2.6 De-Fuzzification

De-Fuzzification is the last step in the FIS to convert the fuzzy number back into a crisp value, which is the desired result of the system. The defuzzifiers also obtain a membership function degree and type from the knowledge base. There are several methods of defuzzification, but this research deployed a centroid method.

4.2.3 Reliability and Validation

The Statistical Packages Social Sciences (SPSS) Statistical software tools was used to test the reliability of the questionnaire. The Cronbach's alpha was carried out to measure the internal consistency with a minimum acceptable level of 0.7. According to Sri Yogi (2015) the Corrected Item Total Correlation (CITC) and Cronbach's alpha if an item is deleted are important measures to test the item reliability and importance to the questionnaire. The CITC indicates the correlation of each item with the score of the overall questionnaire. An item shouldn't be included if its CITC value is less than 0.30. As the name suggests, Cronbach's alpha is calculated again when each item removed. The item was critical if the Cronbach's alpha value of the instrument decreased; this means the item should be retained. If the alpha value increased by deleting the item, the item would be removed to increase the questionnaire's reliability.

Validity is the degree of accuracy to measure a concept. The study utilizes three types of validation: face, contents and construct validity. Face validity was assessed by interviewing experts, while content validity was achieved through rating the factor by experts. Construct validity of the instrument was assessed using factor analysis, Exploratory Factor Analysis (EFA) performed with varimax rotation and eigenvalues greater than one. Prior to conducting the factor analysis, a Kaiser Meyer Olkin (KMO) and Bartlett's test of sphericity were performed to examine the sample adequacy for the factor analysis. The Kaiser Meyer Olkin (KMO) compares the observed correlation coefficients with the partial correlation coefficients (Sri Yogi, 2015). A KMO index can be between 0 and 1, and the minimum acceptable of KMO to conduct factor analysis is 0.6. Bartlett's test of sphericity tests the assumption that the observed correlation matrix is an identity matrix. This research verified that instrument's items are related and that the data was suitable for factor analysis by rejecting the null hypothesis ($P < 0.05$) in Bartlett's test of sphericity tests and obtaining KMO value greater than the minimum. Then, The EFA was performed, where the loading factor considered to be acceptable if it is more than 0.3.

To check the validity of the framework's outcomes, the study implements Fuzzy VIKOR to assess the degree of ranking agreement between the both approaches. Spearman's Rank Correlation utilizes to assets the similarity between the two rankings using the following equation:

$$r_s = 1 - \left[\frac{6.\sum_{j=1}^{k}(di)^2}{k.(k^2-1)}\right] \tag{47}$$

Where j and k represent the number of alternatives, d_i is the difference between the two-rankings.

4.3 Summery

Chapter four of this dissertation expands on the development of the framework for prioritizing areas of improvement in a healthcare system in the context of the business excellence model. The framework development involved two phases; the first phase aimed to identify the vital stakeholders through a stakeholder analysis and evaluation factors selection using FDM. In phase two, the HFS scheme was chosen to build FIS over other schemes due to its ability to reduce the number of fuzzy rules utilized in the database, in addition to being able to determine the relation between the main fuzzy system and the fuzzy subsystems. The HFS consists of four layers: an input layer, an dimensions layer, an intermediate layer, and an integration layer. The number of inputs fed to the input layer depended on the number of the evaluation factors selected in the first phase. The knowledge base construction, including database and fuzzy rules, depend on acquiring knowledge from healthcare expert to quantify the linguistic terms and allocate ambiguous areas. The next chapter illustrates the results of implementing the framework.

CHAPTER 5: IMPLEMENTATION AND RESULTS

5.1 Introduction

To validate the proposed framework, two case studies were conducted to measure its potential. This chapter of the dissertation presents the process of implementing the proposed framework and analyzes the obtained results.

First, the results of the stakeholders' identification and selection are discussed. Then, the results of the FDM phase are presented, including the results from the content validity round, the experts' and stakeholders' selection, and the analysis to elicit the critical factors. Also, this section examines the reliability and validity of the FDM results. Next, the fuzzy system interface development is discussed. The development of FIS included the expert knowledge acquisition step to construct the membership functions and the detailed structure of the FIS model. Each subsystem in the FIS is analyzed and its surface plot is plotted to present the input and output relationships. Finally, a Simulink model was run to compute a priority index and dimensions indices for each improvement opportunity.

5.2 Case studies

The proposed framework tested in two public hospitals in United Arab Emirates. Hospital A is a well-known public hospital located in Abu Dhabi, UAE and offers healthcare in all specialties. It is a 412 acute care medical facility with more than 35 medical departments. The hospital's emergency room and trauma center annually serve around 130,000 patients. Also, more than 18,500 in-patients and 300,000 out-patients annually visit the specialty hospital clinics. The hospital is accredited by the Joint Commission International (JCI).

Hospital B is a specialized public hospital provides care for women and children in Dubai, UAE. It offers specialized medical services including anesthesia and ICU, pediatric surgery, and pediatric medical. Based on the 2017 statistic, the hospital has 468 beds, 60,000 patients were seen in the emergency room, 25,914 in-patients, and 149,640 outpatients. The JCl accredited the hospital in 2007.

5.3 Results of stakeholders' identification

This section details the results of the stakeholders' identification. In order to create a general pattern and select the same stakeholders for the hospitals, two persons from each hospital with different experience and background were involved in the stakeholders' analysis. The participants were from top management and operations authority. An "HCT-k" assigned code was used for each participant, where HCT stands for Healthcare Top Management and k stands for the participant number. The participants were asked to rate the stakeholders based on the necessity of stakeholder involvement (InV) and stakeholder power (P) using the linguistic variables: Very Low (VL), Low (L), Moderate (M), High (H), Very High (VH).

*Table 5-1*and *Table 5-2* contain participants' ratings for stakeholders based on necessity of stakeholder involvement and the stakeholder power, respectively.

Table 5-1: Expert ratings for stakeholders based on necessity of stakeholder involvement

Stakeholder Categories	**Code Initials**	HCT-1	HCT-2	HCT-3	HCT-4
Patients & Families	P&F	VH	H	L	H
Local communities	LC	VH	L	L	H
Commissioning groups	CG	H	VL	VL	M
Insurance companies and other third-party payers	IN	VH	VL	H	H
Other healthcare organizations	HO	M	VL	VL	M
Administrators and managers	A&M	H	M	H	VH
Doctors/physicians	DR	VH	VH	H	VH
Nurses	NR	VH	VH	M	VH
Paramedical staff	PA	M	VH	M	H
Government	GOV	VH	L	VH	H
Authorities	AUT	VH	M	VH	M
Accreditation bodies	ACC	H	L	VL	H
Evaluation committees	EC	H	VH	M	M
Observers (future patients, media, etc.)	OBS	H	L	L	VH
Suppliers	SUP	VH	M	M	VH

Table 5-2: Expert ratings for stakeholders based on stakeholder power

Stakeholder Categories	**Code Initials**	HCT-1	HCT-2	HCT-3	HCT-4
Patients & Families	P&F	VH	L	M	VH
Local communities	LC	VH	VL	M	VH
Commissioning groups	CG	H	VL	VL	M
Insurance companies and other third-party payers	IN	VH	M	H	M
Other healthcare organizations	HO	M	VL	VL	M
Administrators and managers	A&M	H	VH	H	H
Doctors/physicians	DR	VH	H	L	VH
Nurses	NR	VH	H	L	VH
Paramedical staff	PA	M	H	L	H
Government	GOV	VH	VH	H	H
Authorities	AUT	VH	VH	H	M
Accreditation bodies	ACC	H	M	VL	VH
Evaluation committees	EC	H	VH	M	H
Observers (future patients, media, etc.)	OBS	H	L	VL	VH
Suppliers	SUP	VH	L	VL	H

The experts' answers were converted into fuzzy numbers using the membership function in Figure 4-3 and TFN in Table 4-3. Then the fuzzy weights for P and InV were calculated by aggregating participants' opinions using Eq.(30) and Eq.(31), respectively. Finally, the fuzzy weights were converted to crisp values using Eq.(33) and Eq.(34). Results are illustrated in Table 5-3 and *Table 5-3*.

Table 5-3 : Fuzzy weights, average fuzzy weights and crisp values for necessity of stakeholder involvement

Code Initial	HCT-1	HCT-2	HCT-3	HCT-4	Average Fuzzy weight	Crisp value
P&F	[0.75, 1, 1]	[0.5, 0.75, 1]	[0, 0.25, 0.5]	[0.5, 0.75, 1]	[0.44,0.63,0.81]	0.63
LC	[0.75, 1, 1]	[0, 0.25, 0.5]	[0, 0.25, 0.5]	[0.5, 0.75, 1]	[0.31,0.5,0.69]	0.5
CG	[0.5, 0.75, 1]	[0, 0, 0.25]	[0, 0, 0.25]	[0.25, 0.5, 0.75]	[0.19,0.31,0.56]	0.35
IN	[0.75, 1, 1]	[0, 0, 0.25]	[0.5, 0.75, 1]	[0.5, 0.75, 1]	[0.44,0.63,0.81]	0.63
HO	[0.25, 0.5, 0.75]	[0, 0, 0.25]	[0, 0, 0.25]	[0.25, 0.5, 0.75]	[0.13,0.25,0.5]	0.29
A&M	[0.5, 0.75, 1]	[0.25, 0.5, 0.75]	[0.5, 0.75, 1]	[0.75, 1, 1]	[0.5,0.75,0.94]	0.73
DR	[0.75, 1, 1]	[0.75, 1, 1]	[0.5, 0.75, 1]	[0.75, 1, 1]	[0.69,0.94,1]	0.88
NR	[0.75, 1, 1]	[0.75, 1, 1]	[0.25, 0.5, 0.75]	[0.75, 1, 1]	[0.63,0.88,0.94]	0.81
PA	[0.25, 0.5, 0.75]	[0.75, 1, 1]	[0.25, 0.5, 0.75]	[0.5, 0.75, 1]	[0.44,0.69,0.88]	0.67
GOV	[0.75, 1, 1]	[0, 0.25, 0.5]	[0.75, 1, 1]	[0.5, 0.75, 1]	[0.5,0.75,0.88]	0.71
AUT	[0.75, 1, 1]	[0.25, 0.5, 0.75]	[0.75, 1, 1]	[0.25, 0.5, 0.75]	[0.5,0.75,0.88]	0.71
ACC	[0.5, 0.75, 1]	[0, 0.25, 0.5]	[0, 0, 0.25]	[0.5, 0.75, 1]	[0.25,0.5,0.56]	0.44
EC	[0.5, 0.75, 1]	[0.75, 1, 1]	[0.25, 0.5, 0.75]	[0.25, 0.5, 0.75]	[0.44,0.75,0.81]	0.67
OBS	[0.5, 0.75, 1]	[0, 0.25, 0.5]	[0, 0.25, 0.5]	[0.75, 1, 1]	[0.31,0.56,0.75]	0.54
Sup	[0.75, 1, 1]	[0.25, 0.5, 0.75]	[0.25, 0.5, 0.75]	[0.75, 1, 1]	[0.5,0.81,0.81]	0.71

Table 5-4 : Fuzzy weight, average fuzzy weight and crisp value for stakeholder's Power

Code Initial	HCA-1	HCA-2	HCA-3	HCA-4	Average Fuzzy weight	Crisp value
P&F	[0.75, 1, 1]	[0, 0.25, 0.5]	[0.25, 0.5, 0.75]	[0.75, 1, 1]	[0.44,0.69,0.81]	0.65
LC	[0.75, 1, 1]	[0, 0, 0.25]	[0.25, 0.5, 0.75]	[0.75, 1, 1]	[0.44,0.63,0.75]	0.60
CG	[0.5, 0.75, 1]	[0, 0, 0.25]	[0, 0, 0.25]	[0.25, 0.5, 0.75]	[0.19,0.31,0.56]	0.35
IN	[0.75, 1, 1]	[0.25, 0.5, 0.75]	[0.5, 0.75, 1]	[0.25, 0.5, 0.75]	[0.44,0.68,0.88]	0.67
HO	[0.25, 0.5, 0.75]	[0, 0, 0.25]	[0, 0, 0.25]	[0.25, 0.5, 0.75]	[0.13,0.25,0.5]	0.29
A&M	[0.5, 0.75, 1]	[0.75, 1, 1]	[0.5, 0.75, 1]	[0.5, 0.75, 1]	[0.56,0.81,1]	0.79
DR	[0.75, 1, 1]	[0.5, 0.75, 1]	[0, 0.25, 0.5]	[0.75, 1, 1]	[0.5,0.75,0.88]	0.71
NR	[0.75, 1, 1]	[0.5, 0.75, 1]	[0, 0.25, 0.5]	[0.75, 1, 1]	[0.5,0.75,0.875]	0.71
PA	[0.25, 0.5, 0.75]	[0.5, 0.75, 1]	[0, 0.25, 0.5]	[0.5, 0.75, 1]	[0.31,0.63,0.75]	0.56
GOV	[0.75, 1, 1]	[0.75, 1, 1]	[0.5, 0.75, 1]	[0.5, 0.75, 1]	[0.63,0.88,1]	0.83
AUT	[0.75, 1, 1]	[0.75, 1, 1]	[0.5, 0.75, 1]	[0.25, 0.5, 0.75]	[0.56,0.81,0.94]	0.77
ACC	[0.5, 0.75, 1]	[0.25, 0.5, 0.75]	[0, 0, 0.25]	[0.75, 1, 1]	[0.38,0.56,0.75]	0.44
EC	[0.5, 0.75, 1]	[0.75, 1, 1]	[0.25, 0.5, 0.75]	[0.5, 0.75, 1]	[0.5,0.75,0.94]	0.73
OBS	[0.5, 0.75, 1]	[0, 0.25, 0.5]	[0, 0, 0.25]	[0.75, 1, 1]	[0.31,0.5,0.69]	0.50
Sup	[0.75, 1, 1]	[0, 0.25, 0.5]	[0, 0, 0.25]	[0.5, 0.75, 1]	[0.31,0.5,0.63]	0.48

The next step was to calculate the power index (Zhou al., 2016) based on individual participants' inputs using Eq.(29) The final power index for each stakeholder group was aggregated using Eq. (32) then defuzzified using Eq.(35). Results are illustrated in Table 5-5.

Table 5-5 : Fuzzy weight, average fuzzy weight and crisp value for power index

Code Initial	HCA-1	HCA-2	HCA-3	HCA-4	Average Fuzzy weight	Crisp value
P&F	[0.56, 1, 1]	[0, 0.19 ,0.5]	[0, 0, 0.19]	[0.375, 0.75, 1]	[0.23,0.48,0.67]	0.46
LC	[0.56, 1, 1]	[0, 0, 0.06]	[0, 0.13, 0.38]	[0.375, 0.75, 1]	[0.23,0.47,0.61]	0.44
CG	[0.25, 0.56, 1]	[0, 0, 0.06]	[0, 0, 0.06]	[0.06, 0.25, 0.56]	[0.08,0.2,0.42]	0.23
IN	[0.56, 1, 1]	[0, 0, 0.19]	[0.25, 0.56, 1]	[0.13, 0.38, 0.75]	[0.23,0.48,0.73]	0.48
HO	[0.06, 0.25, 0.56]	[0, 0, 0.06]	[0, 0, 0.06]	[0.06, 0.25, 0.56]	[0.03,0.13,0.31]	0.16
A&M	[0.25, 0.56, 1]	[0.19, 0.5, 0.75]	[0.25, 0.56, 1]	[0.36, 0.75, 1]	[0.27,0.59,0.94]	0.60
DR	[0.56, 1, 1]	[0.38, 0.75, 1]	[0, 0.18, 0.5]	[0.56, 1, 1]	[0.38,0.73,0.88]	0.66
NR	[0.56, 1, 1]	[0.38, 0.75, 1]	[0, 0.13, 0.38]	[0.75, 1, 1]	[0.38,0.72,0.84]	0.65
PA	[0.06, 0.25, 0.56]	[0.38, 0.75, 1]	[0, 0.25, 0.19]	[0.25, 0.56, 1]	[0.17,0.45,0.69]	0.44
GOV	[0.56, 1, 1]	[0, 0.25, 0.5]	[0.38, 0.75, 1]	[0.25, 0.56, 1]	[0.3,0.64,0.88]	0.60
AUT	[0.56, 1, 1]	[0.19, 0.5, 0.75]	[0.38, 0.75, 1]	[0.06, 0.25, 0.56]	[0.3,0.63,0.83]	0.58
ACC	[0.25, 0.56, 1]	[0, 0.25, 0.19]	[0, 0, 0.06]	[0.38, 0.75, 0.75]	[0.16,0.39,0.5]	0.35
EC	[0.25, 0.75, 0.75]	[0.56, 1, 1]	[0.06, 0.25, 0.56]	[0.13, 0.38, 0.75]	[0.25,0.59,0.77]	0.54
OBS	[0.25, 0.5, 1]	[0, 0.06, 0.25]	[0, 0, 0.13]	[0.56, 1, 1]	[0.2,0.41,0.59]	0.40
Sup	[0.56, 1, 1]	[0, 0.13, 0.19]	[0, 0, 0.13]	[0.38, 0.75, 1]	[0.23,0.47,0.58]	0.43

Then a power/ necessity of involvement matrix was plotted to find the key players among the stakeholders in Figure 5-1. As seen in the plot, there are several stakeholders allocated to the “key players” zone. In order to limit the data collection process, only the three stakeholders with the highest power index from Table 5-5 were included. Thus, doctors/physicians, nurses, and administrators and managers groups were selected as the vital stakeholders for this study. Although the government group was considered to be one of the vital stakeholders, it was not included in the study due to the associated complicated participation approval process, which did not fit with the research time limitation.

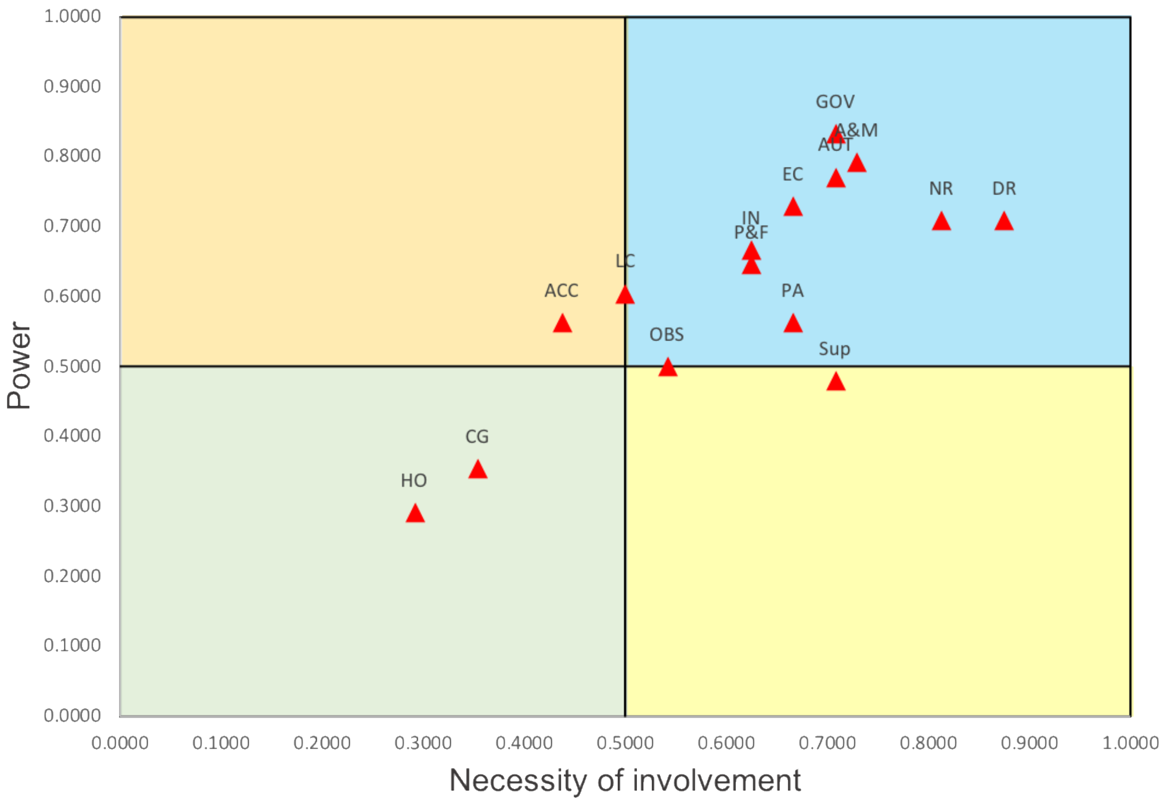


Figure 5-1: Power/necessity of involvement matrix.

5.4 Results of Fuzzy Delphi Method

Based on the literature, twenty evaluation factors were identified and categorized and two evaluation factors (competitive advantage, conformance to contract or accreditation requirements) were added based on the pilot test (Table 5-6). Experts from quality and excellence department in each hospital were invited to participate and in total sixteen experts (E1, E2... E16) responded.

Table 5-6: List of framework's dimensions, evaluation factors, and descriptions

Dimensions	Evaluation factors	Description
Strategical (D1)	Urgency	The extent to which the improvement fulfils the need for an immediate action/ improvement
	Impact/effectiveness	The degree to which the effect of the improvement on the overall organization's outcomes
	Importance/significance	The degree to which the contribution of an improvement to the organization's long-term objectives
	Strategic alignment	The degree to which the improvement objectives aligned with the organization's vision and objectives.
	Critical to quality	The degree to which the improvement will upgrade the quality of service
	Competitive advantage	The likelihood that the improvement will deliver a unique benefit to the patient
Managerial (D2)	Top management commitment	The likelihood that top management will be committed to the improvement
	Learning and growth potential	The likelihood that improvement can improve knowledge and skills
	Conformance to contract or accreditation requirements	To what extent the improvement meets the requirements of accreditation or contract
	Risks	Probability of improvement failure
	Legal implications	The likelihood that there will be legal consequences
	Ethical implications	The likelihood that there will be ethical consequences
Operational Feasibility (D3)	Improvement duration/ Time	The total time needed to complete an improvement from start to end.
	Resource and information availability	The availability of human resources, information, technological capability, and physical asset to support improvement implementation
	Cost	The extent to which the improvement cost is within the organization's budget, including the operation cost
	Ease of implementation	The extent to which the improvement encounters few barriers for implementation

Dimensions	Evaluation factors	Description
	Regulatory compliance	To what extent the improvement meets regulations
Financial impact (D4)	ROI	The degree to which the investment in the improvement yield to considerable return and benefits
	Cost reduction	The degree to which the selected improvement projects should reduce unwarranted expenses to increase profits
	Profit	The degree to which the improvement generates profit for the organization in comparison with the expense incurred
Social (D5)	Patients satisfaction	The extent to which the improvement has the ability to improve patients satisfaction
	Health and safety	To what extent improvement considers health and safety practices

The first round of the FDM asked the experts to validate the list and suggest possible modifications. A week was given to each expert to respond to the survey. This round ended with the addition of six more evaluation factors suggested by the experts: (1) Evidence-based, (2) Sustainability, (3) Replicability, (4) Reputational image, (5) Employee-empowering, and (6) Creativity and Innovation. Table 5-7 demonstrates the results of the first round. The new evaluation factors were included in the second round, as shown in Table 5-8.

Table 5-7: Results of the Fuzzy Delphi validation phase

Hospital	**# of participant**	**Consensus rate**	**Suggested additional factors**	**Factor description**	**Dimension**
A	8	75%	Evidence-based	The degree that the improvement has an evidence of benefit based on research, for example hours of training	Strategical
			Sustainability	The degree that the improvement has the	Strategical

Hospital	# of participant	Consensus rate	Suggested additional factors	Factor description	Dimension
				capability to maintain improvement outcomes.	
B	7	71%	Replicability	The extents to which the improvement is easy to duplicate in another level/ department	Strategical
			Reputational image	The degree of the influence of the improvement on the organization reputation as perceived by the public	Social
			Employee empowerment	To what extend the improvement increases the degree of employee skills and authority	Operational Feasibility
			Creativity and Innovation	The degrees of improvement creativity and innovation	Strategical

Table 5-8: Revised list of framework's and evaluation factors after Fuzzy Delphi round 1

Dimensions	Evaluation factors
Strategical (D1)	Urgency (C1)
	Impact/effectiveness (C2)
	Importance/significance (C3)
	Strategic alignment (C4)
	Critical to quality (C5)
	Competitive advantage (C6)
	Sustainability (C7)
	Replicability (C8)
	Evidence based (C9)
	Creativity and Innovation (C10)
Managerial (D2)	Top management commitment (C11)
	Learning and growth potential (C12)
	Conformance to contract or accreditation requirements (C13)
	Risks (C14)
	Legal implications (C15)
	Ethical implications (C16)
Operational Feasibility (D3)	Improvement duration/ Time (C17)

Dimensions	Evaluation factors
	Resource and information availability (C18)
	Cost (C19)
	Ease of implementation (C20)
	Regulatory compliance (C21)
	Employee empowerment (C22)
Financial impact (D2)	ROI (C23)
	Cost reduction (C24)
	Profit (C25)
Social (D3)	Patients satisfaction (C26)
	Health and safety (C27)
	Reputational image (C28)

The second round attempted to incorporate input from the stakeholders identified in Table 5-5 (doctors/physicians, nurses, and administrators /managers) in addition to experts. From each group a sample size was selected based on the total population published on the hospitals' website. The sample size was calculated using a 95-confidence interval and 5% margin error.

Table 5-9 illustrates the actual population

Table 5-9: Sample size from each hospital

	Actual population			Sample size		
Staff category / Hospital name	Doctors and Physicians	Nurses	Managers and Administrators	Doctors and Physicians	Nurses	Managers and Administrators
Hospital A	290	863	311	166	266	172
Hospital B	167	815	240	117	261	148

In the second round, the participants were provided with the revised list of framework's dimensions and evaluation factors and asked to assign an importance weight to each evaluation factor (C1, C2, C3… C28) using the five linguistic variables Very Unimportant (VU), Unimportant (U), Moderately Important (MI), Important (I), and Very Important (VI). Though round two was originally scheduled to take a week, in reality it took three weeks to increase the response rate, especially for the doctors and managers groups. In the second week a reminder was sent and in the third week, responses were collected as hardcopies. Some responses were excluded due to missing data. Table 5-10 illustrates the number of the received responses, number of the included responses, and the response rate from each stakeholder group in each hospital.

Table 5-10: Responses from each hospital

Staff category / Hospital	Experts	Received: Doctors and Physicians	Included: Doctors and Physicians	Response rate (%)	Received: Nurses	Included: Nurses	Response rate (%)	Received: Managers and Administrators	Included: Managers and Administrators	Response rate (%)
Hospital A	8	91	61	36.7	260	182	68.4	72	58	33.7
Hospital B	7	61	32	27.4	198	152	58.2	58	37	25.0

5.4.1 Results for hospital A

In the next step, after all of the experts' judgements were received for the second list (Table 5-11), experts' judgments were converted to TFN using Table 4-4 and Excel macros was written to automate the process (Appendix J). Then the fuzzy weights for each criterion were aggregated using the average mean employing Eq.(37). The aggregated results are presented in

Table *5-12*. Next, the fuzzy numbers were then converted to crisp real numbers through the defuzzification process using the average method (Eq.(40)). These numbers are listed in the last column of Table 5-12.

Table 5-11: Experts' evaluation of factors' importance in Hospital A

	E1	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E8**
C1	VU	MI	I	MI	MI	VI	MI	I
C2	VU	I	I	MI	I	VI	I	VI
C3	VI	I	I	MI	I	VI	MI	VI
C4	VI	VI	I	MI	I	VI	VI	VI
…	…	…	…	…	…	…	…	…
C25	VI	U	H	MI	I	MI	MI	U
C26	VI	I	I	MI	I	VI	I	VI
C27	VI	VI	I	MI	I	VI	VI	VI
C28	VI	I	I	I	I	VI	VI	VI

Table 5-12: Fuzzy number and average fuzzy weight for each evaluation factors based on experts' rating in Hospital A

	E1	**E2**	**…**	**E7**	**E8**	Average Fuzzy weighting	Crisp value
C1	(0,0,0.25)	(0.25,0.5,0.75)	…	(0.25,0.5,0.75)	(0.5,0.75,1)	(0.47,0.71,0.91)	0.6979
C2	(0,0,0.25)	(0.5, 0.75,1)	…	(0.5, 0.75,1)	(0.75,1,1)	(0.56,0.81,0.97)	0.7813
C3	(0.75,1,1)	(0.5, 0.75,1)	…	(0.25,0.5,0.75)	(0.75,1,1)	(0.53,0.78,0.93)	0.7500
C4	(0.75,1,1)	(0.75,1,1)	…	(0.75,1,1)	(0.75,1,1)	(0.63,0.88,0.97)	0.8229
…	…	…	…	…	…	…	…
C25	(0.75,1,1)	(0.25,0.5,0.75)	…	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0.31,0.56,0.78)	0.5521
C26	(0.75,1,1)	(0.5, 0.75,1)	…	(0.5, 0.75,1)	(0.75,1,1)	(0.56,0.81,0.97)	0.7813
C27	(0.75,1,1)	(0.75,1,1)	…	(0.75,1,1)	(0.75,1,1)	(0.63, 0.88,0.97)	0.8229
C28	(0.75,1,1)	(0.5, 0.75,1)	…	(0.75,1,1)	(0.75,1,1)	(0.56, 0.81, 1)	0.7917

A criterion was retained or removed according to whether it fulfilled t2qhe three conditions identified in chapter 4. Thus, in addition to the average fuzzy number obtained in the previous step, the average distance between expert fuzzy number and the average fuzzy number to measure the experts' consensus, and the agreement level were calculated using Eq.(42) and

Eq.(43), respectively. Once the three values were obtained, each value was tested to satisfy the corresponding conditions. Table 5-13 illustrates the results of this step.

Table 5-13: Experts' results for the three conditions and the final decision in Hospital A

Evaluation factor	d-value	% group agreement	Factor importa nce	Verdict
Urgency (C1)	0.1565	25%	0.6979	Remove
Impact/effectiveness (C2)	0.1205	50%	0.7813	Remove
Importance/significance (C3)	0.1484	50%	0.7500	Remove
Strategic alignment (C4)	0.1321	50%	0.8229	Remove
Critical to quality (C5)	0.1484	50%	0.7500	Remove
Competitive advantage (C6)	0.1929	38%	0.5521	Remove
Sustainability (C7)	0.0957	63%	0.8125	**Retain**
Replicability (C8)	0.1871	25%	0.7188	Remove
Evidence based (C9)	0.1324	63%	0.8021	**Retain**
Creativity and Innovation (C10)	0.1276	50%	0.7292	Remove
Top management commitment (C11)	0.0765	63%	0.8750	**Retain**
Learning and growth potential (C12)	0.1565	25%	0.6979	Remove
Conformance to contract or accreditation requirements (C13)	0.1636	38%	0.7708	Remove
Risks (C14)	0.1532	50%	0.7500	Remove
Legal implications (C15)	0.0957	63%	0.8125	**Retain**
Ethical implications (C16)	0.1021	63%	0.8333	**Retain**
Improvement duration/ Time (C17)	0.1730	50%	0.6667	Remove
Resource and information availability (C18)	0.1636	50%	0.7708	Remove
Cost (C19)	0.1276	25%	0.7292	Remove
Ease of implementation (C20)	0.2264	25%	0.6563	Remove
Regulatory compliance (C21)	0.1324	50%	0.8021	Remove
Employee empowerment (C22)	0.1764	25%	0.7188	Remove
ROI (C23)	0.1250	63%	0.6250	Remove
Cost reduction (C24)	0.1799	50%	0.6146	Remove
Profit (C25)	0.1929	38%	0.5521	Remove
Patients satisfaction (C26)	0.1205	50%	0.7813	Remove
Health and safety (C27)	0.1321	50%	0.8229	Remove
Reputational image (C28)	0.0765	63%	0.7917	**Retain**

The same calculation above were repeated again for the other three stakeholder groups in order to find the preferred factors for each group. Table 5-14, Table 5-15, and Table 5-16 present the results for the critical factors from the physicians' perspective, while Table 5-17, Table 5-18 and Table 5-19 present the results for the nurses group. Finally, Table 5-20, Table 5-21, and Table 5-22 are the tables for the managers and administrators group.

Table 5-14: Physicians' evaluation of factors' importance in Hospital A

	PHY1	**PHY2**	**PHY4**	**PHY4**	**…**	**PHY59**	**PHY60**	**PHY61**
C1	U	MI	MI	MI	…	MI	MI	VI
C2	U	I	MI	VI	…	I	I	VI
C3	U	I	MI	U	…	MI	MI	VI
C4	U	I	MI	U	…	I	MI	VI
C5	U	I	MI	MI	…	MI	MI	I
C6	U	MI	MI	VU	…	MI	MI	VI
C7	U	I	MI	MI	…	MI	MI	I
C8	U	MI	MI	VI	…	MI	MI	I
…	…	…	…	…	…	…	…	…
C25	U	I	MI	I	…	MI	MI	I
C26	U	MI	MI	I	…	MI	MI	MI
C27	MI	VI	MI	VI	…	MI	MI	MI
C28	MI	VI	MI	VI	…	MI	MI	I

Table 5-15: Fuzzy number and average fuzzy weight for the factors based on physicians' rating in hospital A

	PHY1	**PHY2**	**…**	**PHY60**	**PHY61**	Average Fuzzy weighting	Crisp value
C1	(0,0.25, 0.5)	(0.25,0.5,0.75)	…	(0.25,0.5,0.75)	(0.75,1,1)	(0.38,0.62,0.85)	0.6139
C2	(0,0.25, 0.5)	(0.5, 0.75,1)	…	(0.5, 0.75,1)	(0.75,1,1)	(0.40,0.64, 0.87)	0.6361
C3	(0,0.25, 0.5)	(0.5, 0.75,1)	…	(0.25,0.5,0.75)	(0.75,1,1)	(0.40,0.65,0.88)	0.6486
C4	((0,0.25, 0.5)	(0.5, 0.75,1)	…	(0.25,0.5,0.75)	(0.75,1,1)	(0.37,0.61,0.84)	0.6042
C5	(0,0.25, 0.5)	(0.5, 0.75,1)	…	(0.25,0.5,0.75)	(0.5, 0.75,1)	(0.41,0.66,0.88)	0.6514
C6	(0,0.25, 0.5)	(0.25,0.5,0.75)	…	(0.25,0.5,0.75)	(0.75,1,1)	(0.38,0.61,0.84)	0.6125
C7	(0,0.25, 0.5)	(0.5, 0.75,1)	…	(0.25,0.5,0.75)	(0.5, 0.75,1)	(0.40,0.64,0.85)	0.6333
C8	(0,0.25, 0.5)	(0.25,0.5,0.75)	…	(0.25,0.5,0.75)	(0.5, 0.75,1)	(0.41,0.65,0.86)	0.6403
…	…	…	…	…	…	…	…
C25	(0,0.25, 0.5)	(0.5, 0.75,1)	…	(0.25,0.5,0.75)	(0.5, 0.75,1)	(0.45,0.69,0.88)	0.5389
C26	(0,0.25, 0.5)	(0.25,0.5,0.75)	…	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0.43,0.67,0.86)	0.6764
C27	(0.25,0.5,0.75)	(0.75,1,1)	…	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0.38,0.62,0.85)	0.6958
C28	(0.25,0.5,0.75)	(0.75,1,1)	…	(0.25,0.5,0.75)	(0.75,1,1)	(0.40,0.64,0.87)	0.6556

Table 5-16: Physicians' result for the three conditions and the final decision in hospital A

Evaluation factor	d-value	% group agreement	Factor importance	Verdict
Urgency (C1)	0.1864	72%	0.6139	Remove
Impact/effectiveness (C2)	0.1700	78%	0.6361	Remove
Importance/significance (C3)	0.1595	80%	0.6486	Remove
Strategic alignment (C4)	0.1696	82%	0.6042	Remove
Critical to quality (C5)	0.1769	72%	0.6514	**Retain**
Competitive advantage (C6)	0.1931	72%	0.6125	Remove
Sustainability (C7)	0.1877	72%	0.6333	Remove
Replicability (C8)	0.1962	63%	0.6403	Remove
Evidence based (C9)	0.1969	68%	0.6056	Remove
Creativity and Innovation (C10)	0.1924	70%	0.6292	Remove
Top management commitment (C11)	0.1860	73%	0.6278	Remove
Learning and growth potential (C12)	0.1971	70%	0.6236	Remove
Conformance to contract or accreditation requirements (C13)	0.1608	85%	0.6181	Remove
Risks (C14)	0.1887	72%	0.6208	Remove
Legal implications (C15)	0.1877	68%	0.6403	Remove
Ethical implications (C16)	0.2140	63%	0.6083	Remove
Improvement duration/ Time (C17)	0.1673	83%	0.5833	Remove
Resource and information availability (C18)	0.1761	82%	0.6153	Remove
Cost (C19)	0.1836	77%	0.5917	Remove
Ease of implementation (C20)	0.1816	77%	0.6222	Remove
Regulatory compliance (C21)	0.1693	78%	0.6278	Remove
Employee empowerment (C22)	0.2082	65%	0.5792	Remove
ROI (C23)	0.1575	82%	0.5819	Remove
Cost reduction (C24)	0.1490	78%	0.5528	Remove
Profit (C25)	0.1597	47%	0.5389	Remove
Patients satisfaction (C26)	0.1826	67%	0.6764	**Retain**
Health and safety (C27)	0.1656	67%	0.6958	**Retain**
Reputational image (C28)	0.1878	67%	0.6556	**Retain**

Table 5-17: Nurses' evaluation for factors' importance in Hospital A

	NUR1	NUR2	NUR3	NUR4	…	NUR180	NUR181	NUR182
C1	I	MI	MI	I	…	I	VI	VI
C2	I	MI	I	I	…	I	MI	VI
C3	I	MI	I	I	…	I	MI	VI
C4	I	MI	MI	I	…	I	I	VI
C5	I	MI	MI	I	…	VI	I	VI
C6	I	MI	MI	I	…	VU	I	VI
C7	I	MI	MI	I	…	MI	MI	VI
C8	MI	MI	I	I	…	I	MI	I
…	…	…	…	…	…	…	…	…
C25	I	MI	MI	I	…	I	I	VI
C26	MI	MI	I	I	…	I	I	VI
C27	I	MI	I	I	…	VI	I	VI
C28	I	MI	I	I	…	MI	I	VI

Table 5-18: Fuzzy number and average fuzzy weight for the factors based on nurses' rating in hospital A

	NUR1	NUR2	…	NUR181	NUR182	Average Fuzzy weighting	Crisp value
C1	(0.5, 0.75,1)	(0.25,0.5,0.75)	…	(0.75,1,1)	(0.75,1,1)	(0.39,0.64,0.87)	0.6321
C2	(0.5, 0.75,1)	(0.25,0.5,0.75)	…	(0.25,0.5,0.75)	(0.75,1,1)	(0.40,0.65,0.88)	0.6462
C3	(0.5, 0.75,1)	(0.25,0.5,0.75)	…	(0.25,0.5,0.75)	(0.75,1,1)	(0.40,0.65,0.88)	0.6397
C4	(0.5, 0.75,1)	(0.25,0.5,0.75)	…	(0.5, 0.75,1)	(0.75,1,1)	(0.38,0.63,0.87)	0.6295
C5	(0.5, 0.75,1)	(0.25,0.5,0.75)	…	(0.5, 0.75,1)	(0.75,1,1)	(0.42,0.67,0.88)	0.6551
C6	(0.5, 0.75,1)	(0.25,0.5,0.75)	…	(0.5, 0.75,1)	(0.75,1,1)	(0.37,0.62,0.86)	0.6179
C7	(0.5, 0.75,1)	(0.25,0.5,0.75)	…	(0.25,0.5,0.75)	(0.75,1,1)	(0.39,0.64,0.87)	0.6359
C8	(0.25,0.5,0.75)	(0.25,0.5,0.75)	…	(0.25,0.5,0.75)	(0.5, 0.75,1)	(0.36,0.61,0.85)	0.6077
…	…	…	…	…	…	…	…
C25	(0.5, 0.75,1)	(0.25,0.5,0.75)	…	(0.5, 0.75,1)	(0.75,1,1)	(0.36,0.61,0.85)	0.6038
C26	(0.25,0.5,0.75)	(0.25,0.5,0.75)	…	(0.5, 0.75,1)	(0.75,1,1)	(0.36,0.61,0.85)	0.6577
C27	(0.5, 0.75,1)	(0.25,0.5,0.75)	…	(0.5, 0.75,1)	(0.75,1,1)	(0.42,0.67,0.88)	0.6731
C28	(0.5, 0.75,1)	(0.25,0.5,0.75)	…	(0.5, 0.75,1)	(0.75,1,1)	(0.44,0.69,0.89)	0.6500

Table 5-19: Nurses' results for the three conditions and the final decision in Hospital A

Evaluation factor	Threshold value	% group agreement	Average fuzzy number	Verdict
Urgency (C1)	0.1468	88%	0.6321	Remove
Impact/effectiveness (C2)	0.1428	89%	0.6462	Remove
Importance/significance (C3)	0.1411	91%	0.6397	Remove
Strategic alignment (C4)	0.1388	92%	0.6295	Remove
Critical to quality (C5)	0.1456	87%	0.6551	**Retain**
Competitive advantage (C6)	0.1425	90%	0.6179	Remove
Sustainability (C7)	0.1423	90%	0.6359	Remove
Replicability (C8)	0.1469	84%	0.6077	Remove
Evidence based (C9)	0.1436	86%	0.6667	**Retain**
Creativity and Innovation (C10)	0.1528	86%	0.6141	Remove
Top management commitment (C11)	0.1441	89%	0.6385	Remove
Learning and growth potential (C12)	0.1502	86%	0.6513	**Retain**
Conformance to contract or accreditation requirements (C13)	0.1411	90%	0.6372	Remove
Risks (C14)	0.1460	88%	0.6077	Remove
Legal implications (C15)	0.1447	90%	0.6474	Remove
Ethical implications (C16)	0.1486	88%	0.6385	Remove
Improvement duration/ Time (C17)	0.1366	93%	0.6115	Remove
Resource and information availability (C18)	0.1443	89%	0.6295	Remove
Cost (C19)	0.1376	90%	0.5987	Remove
Ease of implementation (C20)	0.1398	92%	0.6167	Remove
Regulatory compliance (C21)	0.1418	91%	0.6346	Remove
Employee empowerment (C22)	0.1650	81%	0.6128	Remove
ROI (C23)	0.1391	90%	0.6077	Remove
Cost reduction (C24)	0.1393	91%	0.6128	Remove
Profit (C25)	0.1350	92%	0.6038	Remove
Patients satisfaction (C26)	0.1544	82%	0.6577	**Retain**
Health and safety (C27)	0.1525	79%	0.6731	**Retain**
Reputational image (C28)	0.1450	87%	0.6500	**Retain**

Table 5-20: Managers and administrators' evaluation of factors' importance in Hospital A

	M&A1	M&A2	M&A3	M&A4	…	M&A39	M&A40	M&A41
C1	I	VI	VI	MI	…	VU	I	I
C2	I	VI	I	MI	…	MI	MI	I
C3	I	I	I	I	…	I	MI	I
C4	VI	I	I	MI	…	I	MI	VI
C5	I	VI	VI	MI	…	MI	MI	I
C6	I	I	VI	U	…	I	U	I
C7	I	VI	VI	MI	…	I	MI	I
C8	I	I	VI	MI	…	MI	U	I
…	…	…	…	…	…	…	…	…
C25	I	I	VI	MI	…	U	MI	I
C26	VI	I	I	I	…	MI	MI	I
C27	VI	VI	I	MI	…	MI	MI	I
C28	I	VI	I	MI	…	MI	MI	VI

Table 5-21: Fuzzy number and average fuzzy weight for the factors based on Managers and administrators' rating in Hospital A

	M&A1	M&A2	…	M&A40	M&A41	Average Fuzzy weighting	Crisp value
C1	(0.5, 0.75,1)	(0.75, 1, 1)	…	(0.5, 0.75,1)	(0.5, 0.75,1)	(0.40,0.64,0.86)	0.6360
C2	(0.5, 0.75,1)	(0.75, 1, 1)	…	(0.25,0.5,0.75)	(0.5, 0.75,1)	(0.41,0.66,0.88)	0.6491
C3	(0.5, 0.75,1)	(0.5, 0.75,1)	…	(0.25,0.5,0.75)	(0.5, 0.75,1)	(0.40,0.65,0.87)	0.6379
C4	(0.75, 1, 1)	(0.5, 0.75,1)	…	(0.25,0.5,0.75)	(0.75, 1, 1)	(0.39,0.64,0.86)	0.6322
C5	(0.5, 0.75,1)	(0.75, 1, 1)	…	(0.25,0.5,0.75)	(0.5, 0.75,1)	(0.44,0.69,0.89)	0.6769
C6	(0.5, 0.75,1)	(0.5, 0.75,1)	…	(0,0.25,0.5)	(0.5, 0.75,1)	(0.38,0.62,0.83)	0.6096
C7	(0.5, 0.75,1)	(0.75, 1, 1)	…	(0.25,0.5,0.75)	(0.5, 0.75,1)	(0.41,0.66,0.87)	0.6748
C8	(0.5, 0.75,1)	(0.5, 0.75,1)	…	(0,0.25,0.5)	(0.5, 0.75,1)	(0.35,0.59,0.82)	0.5862
…	…	…	…	…	…	…	…
C25	(0.5, 0.75,1)	(0.5, 0.75,1)	…	(0.25,0.5,0.75)	(0.5, 0.75,1)	(0.40,0.64,0.86)	0.6336
C26	(0.75, 1, 1)	(0.5, 0.75,1)	…	(0.25,0.5,0.75)	(0.5, 0.75,1)	(0.50,0.75,0.90)	0.7135
C27	(0.75, 1, 1)	(0.25,0.5,0.75)	…	(0.25,0.5,0.75)	(0.5, 0.75,1)	(0.52,0.76,0.91)	0.7295
C28	(0.5, 0.75,1)	(0.25,0.5,0.75)	…	(0.25,0.5,0.75)	(0.75, 1, 1)	(0.45,0.69,0.89)	0.6769

Table 5-22: Managers and administrators' results for the three conditions and the final decision in Hospital A

Evaluation factor	d-value	% group agreement	Factor importa nce	Verdict
Urgency (C1)	0.1910	74%	0.6360	Remove
Impact/effectiveness (C2)	0.1697	79%	0.6491	Remove
Importance/significance (C3)	0.1748	78%	0.6379	Remove
Strategic alignment (C4)	0.1650	81%	0.6322	Remove
Critical to quality (C5)	0.1715	74%	0.6769	**Retain**
Competitive advantage (C6)	0.1961	72%	0.6096	Remove
Sustainability (C7)	0.1535	80%	0.6748	**Retain**
Replicability (C8)	0.1882	69%	0.5862	Remove
Evidence based (C9)	0.1775	71%	0.6695	**Retain**
Creativity and Innovation (C10)	0.2060	67%	0.6236	Remove
Top management commitment (C11)	0.1936	67%	0.6566	**Retain**
Learning and growth potential (C12)	0.1932	69%	0.6466	Remove
Conformance to contract or accreditation requirements (C13)	0.1751	78%	0.6535	**Retain**
Risks (C14)	0.2043	71%	0.6324	Remove
Legal implications (C15)	0.1919	71%	0.6491	Remove
Ethical implications (C16)	0.1858	71%	0.6580	**Retain**
Improvement duration/ Time (C17)	0.1757	79%	0.6264	Remove
Resource and information availability (C18)	0.1654	81%	0.6451	Remove
Cost (C19)	0.1824	74%	0.6250	Remove
Ease of implementation (C20)	0.1821	76%	0.6193	Remove
Regulatory compliance (C21)	0.1888	72%	0.6293	Remove
Employee empowerment (C22)	0.1898	69%	0.6509	**Retain**
ROI (C23)	0.1637	83%	0.6207	Remove
Cost reduction (C24)	0.1647	83%	0.6307	Remove
Profit (C25)	0.1638	83%	0.6336	Remove
Patients satisfaction (C26)	0.2006	29%	0.7135	Remove
Health and safety (C27)	0.1960	71%	0.7295	**Retain**
Reputational image (C28)	0.1805	71%	0.6769	**Retain**

Table 5-23 illustrates the factors retained from each group as a result of the above calculations. A critical factor was selected if it was common between two or more groups The Venn diagram in Figure 5-2 demonstrates the intersections among the groups. Notice that factors falling into only one set aren't considered critical factors. After the critical factors were determined, the total weight of each factor was calculated using Eq.(38). Results are illustrated in Table 5-24.

Table 5-23: Retained factors from each group

Experts	Doctors and Physicians	Nurses	Managers and Administrators
Top management commitment	Health and safety	Health and safety	Health and safety
Ethical implication	Patients satisfaction	Evidence based	Critical to quality
Sustainability	Reputational image	Patients satisfaction	Sustainability
Legal implication	Critical to quality	Critical to quality	Reputational image
Evidence based		Learning and growth potential	Evidence based
Reputational image		Reputational image	Employee empowerment
			Ethical implication
			Top management commitment
			Ethical implication

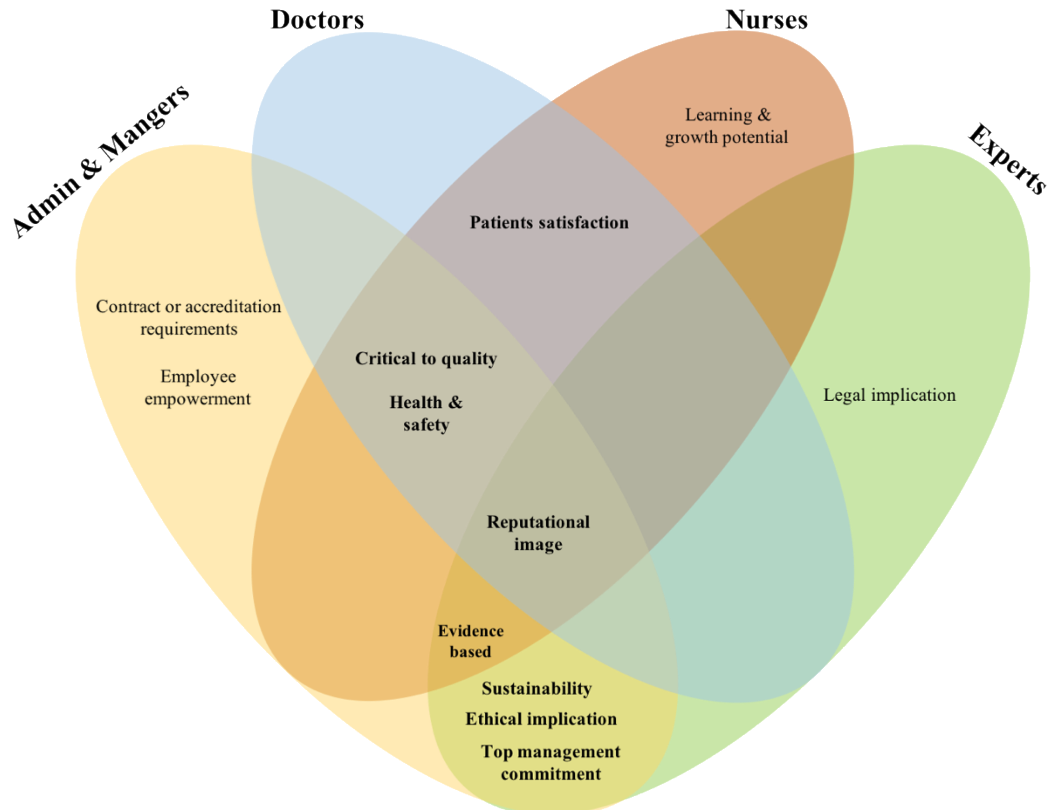


Figure 5-2: Venn Diagram for selected factors of the four groups.

Table 5-24: Factors selected for Hospital A

Ranking	Evaluation factors	Fuzzy weight for the selected factor	Total weight's crisp value
1	Health and safety	[0.51,0.76,0.92]	0.73
2	Top management commitment	[0.48,0.72,0.90]	0.70
3	Patients satisfaction	[0.48,0.73,0.91]	0.71
4	Reputational image	[0.46,0.71,0.91]	0.69
5	Ethical implication	[0.46,0.70,0.89]	0.68

Ranking	Evaluation factors	Fuzzy weight for the selected factor	Total weight's crisp value
6	Evidence based	[0.46,0.70,0.89]	0.68
7	Sustainability	[0.45,0.70,0.90]	0.68
8	Critical to quality	[0.45,0.70,0.90]	0.68

5.4.2 Results for Hospital B

The same steps were repeated again to collect the results for hospital B, first experts, physicians, nurses, managers and administration judgements were collected as shown in Table 5-25 Table 5-27, Table 5-29, and Table 5-31 respectively. Then using macro code, the judgments for each group were converted into TFN, average fuzzy weights were found through utilizing Eq.(37), and the defuzzifier converted the fuzzy number into crisp values by employing Eq.(41). The result of those steps illustrated in Table 5-26, Table 5-28,Table 5-30 and Table 5-32.

Table 5-25: Experts' evaluation for factors' importance in Hospital B

	E1	**E2**	**…**	**E5**	**E6**	**E7**
C1	VI	MI	…	MI	MI	MI
C2	VI	I	…	VI	VI	MI
C3	VI	VI	…	I	I	MI
C4	VI	U	…	MI	I	MI
C5	VI	I	…	I	I	MI
…	…	…	…	…	…	…
C25	VI	MI	…	MI	I	MI
C26	VI	U	…	I	I	MI
C27	VI	VI	**…**	U	I	MI
C28	I	VI	…	MI	I	MI

Table 5-26: Fuzzy number and average fuzzy weight for the factors from experts' perspectives in Hospital B

	E1	**E2**	**…**	**E7**	Average Fuzzy weighting	Crisp value
C1	(0.75,1,1)	(0.25,0.5,0.75)	…	(0.25,0.5,0.75)	(0.42,0.67,0.88)	0.6528
C2	(0.75,1,1)	(0.5, 0.75,1)	…	(0.25,0.5,0.75)	(0.50,0.75,0.96)	0.7361
C3	(0.75,1,1)	(0.75,1,1)	…	(0.25,0.5,0.75)	(0.46,0.71,0.92)	0.6944
C4	(0.75,1,1)	(0,0.25,0.5)	…	(0.25,0.5,0.75)	(0.5,0.75,0.92)	0.7222
C5	(0.75,1,1)	(0.5, 0.75,1)	…	(0.25,0.5,0.75)	(0.54,0.79,0.96)	0.7639
C6	(0.75,1,1)	(0.25,0.5,0.75)	…	(0.25,0.5,0.75)	(0.38,0.63,0.83)	0.6111
C7	(0.5, 0.75,1)	(0.5, 0.75,1)	…	(0.25,0.5,0.75)	(0.54,0.79,0.96)	0.7639
C8	0.5, 0.75,1)	(0,0.25,0.5)	…	(0.25,0.5,0.75)	(0.46, 0.71,0.88)	0.6806
…	…	…	…	…	…	…
C25	(0.75,1,1)	(0.25,0.5,0.75)	…	(0.25,0.5,0.75)	(0.42,0.67,0.88)	0.6528
C26	(0.75,1,1)	(0,0.25,0.5)	…	(0.25,0.5,0.75)	(0.5,0.75,0.96)	0.7361
C27	(0.75,1,1)	(0.75,1,1)	…	(0.25,0.5,0.75)	(0.54,0.79,0.96)	0.7639
C28	(0.5, 0.75,1)	(0.75,1,1)	…	(0.25,0.5,0.75)	(0.54,0.79,1)	0.7778

Table 5-27: Physicians' evaluation for factors' importance in hospital B

	PHY1	**PHY2**	**PHY4**	**…**	**PHY30**	**PHY31**	**PHY32**
C1	MI	I	U	…	MI	MI	I
C2	MI	I	VI	…	MI	I	I
C3	MI	VI	U	…	MI	I	I
C4	MI	I	MI	…	MI	MI	I
C5	MI	VI	MI	…	MI	MI	I
C6	VU	VI	MI	…	MI	I	VI
C7	MI	MI	MI	…	MI	I	I
C8	MI	MI	MI	…	MI	I	I
…	…	…	…	…	…	…	…
C25	U	I	I	…	MI	I	I
C26	U	VI	I	…	MI	MI	VI
C27	MI	MI	U	…	MI	MI	VI
C28	VU	MI	MI	…	MI	MI	VI

Table 5-28: Fuzzy number and average fuzzy weight for the factors from doctors and physicians' perspectives in Hospital B

	PHY1	**PHY2**	**…**	**PHY32**	Average Fuzzy weighting	Crisp value
C1	(0.25,0.5,0.75)	(0.5,0.75,1)	…	(0.5,0.75,1)	(0.32,0.57,0.81)	0.5677
C2	(0.25,0.5,0.75)	(0.5,0.75,1)	…	(0.5,0.75,1)	(0.40,0.65,0.88)	0.6432
C3	(0.25,0.5,0.75)	(0.75,1,1)	…	(0.5,0.75,1)	(0.38,0.63,0.86)	0.6250
C4	(0.25,0.5,0.75)	(0.5,0.75,1)	…	(0.5,0.75,1)	(0.32,0.61,0.84)	0.5651
C5	(0.25,0.5,0.75)	(0.75,1,1)	…	(0.5,0.75,1)	(0.39,0.64,0.87)	0.6016
C6	(0,0,025)	(0.75,1,1)	…	(0.75,1,1)	(0.39,0.64,0.85)	0.6328
C7	(0.25,0.5,0.75)	(0.25,0.5,0.75)	…	(0.5,0.75,1)	(0.37,0.62,0.85)	0.6276
C8	(0.25,0.5,0.75)	(0.25,0.5,0.75)	…	(0.5,0.75,1)	(0.42,0.66,0.88)	0.6120
…	…	…	…	…	…	…
C25	(0,0.25,0.5)	(0.5,0.75,1)	…	(0.5,0.75,1)	(0.35,0.60,0.84)	0.5990
C26	(0,0.25,0.5)	(0.75,1,1)	…	(0.5,0.75,1)	(0.44,0.69,0.88)	0.6667
C27	(0.25,0.5,0.75)	(0.25,0.5,0.75)	…	(0.75,1,1)	(0.45,0.70,0.88)	0.6771
C28	(0,0,025)	(0.25,0.5,0.75)	…	(0.75,1,1)	(0.40,0.65,0.86)	0.6354

Table 5-29: Nurses' evaluation for factors' importance in Hospital B

	NUR1	**NUR2**	**NUR3**	**…**	**NUR155**	**NUR156**	**NUR157**
C1	I	MI	U	…	U	MI	MI
C2	I	MI	U	…	MI	MI	MI
C3	I	MI	U	…	MI	MI	I
C4	I	MI	VU	…	MI	MI	MI
C5	I	I	I	…	MI	U	MI
C6	VI	I	VU	…	I	U	MI
C7	MI	MI	VI	…	MI	U	MI
C8	VI	MI	MI	…	U	U	MI
…	…	…	…	…	…	…	…
C25	VI	I	I	…	I	U	MI
C26	VI	I	MI	…	I	MI	MI
C27	VI	I	U	…	I	MI	MI
C28	VI	I	U	…	I	MI	MI

Table 5-30: Fuzzy number and average fuzzy weight for the factors from nurses' perspectives in Hospital B

	NUR1	**NUR2**	**…**	**NUR157**	Average Fuzzy weighting	Crisp value
C1	(0.5,0.75,1)	(0.25,0.5,0.75)	…	(0.25,0.5,0.75)	(0.36,0.61,0.85)	0.6052
C2	(0.5,0.75,1)	(0.25,0.5,0.75)	…	(0.25,0.5,0.75)	(0.36,0.61,0.85)	0.6071
C3	(0.5,0.75,1)	(0.25,0.5,0.75)	…	(0.5,0.75,1)	(0.37,0.62,0.85)	0.6131
C4	(0.5,0.75,1)	(0.25,0.5,0.75)	…	(0.25,0.5,0.75)	(0.36,0.61,0.85)	0.6052
C5	(0.5,0.75,1)	(0.5,0.75,1)	…	(0.25,0.5,0.75)	(0.34,0.59,0.83)	0.5853
C6	(0.75,1,1)	(0.5,0.75,1)	…	(0.25,0.5,0.75)	(0.36,0.61,0.85)	0.6032
C7	(0.25,0.5,0.75)	(0.25,0.5,0.75)	…	(0.25,0.5,0.75)	(0.35,0.60,0.83)	0.5952
C8	(0.75,1,1)	(0.25,0.5,0.75)	…	(0.25,0.5,0.75)	(0.33,0.58,0.82)	0.5734
…	…	…	…	…	…	…
C25	(0.75,1,1)	(0.5,0.75,1)	…	(0.25,0.5,0.75)	(0.29,0.54,0.78)	0.5337
C26	(0.75,1,1)	(0.5,0.75,1)	…	(0.25,0.5,0.75)	(0.39,0.64,0.86)	0.6290
C27	(0.75,1,1)	(0.5,0.75,1)	…	(0.25,0.5,0.75)	(0.42,0.67,0.88)	0.6548
C28	(0.75,1,1)	(0.5,0.75,1)	…	(0.25,0.5,0.75)	(0.40,0.65,0.88)	0.6409

Table 5-31: Managers and administrators' evaluation for factors' importance in Hospital B

	M&A1	**M&A2**	**M&A3**	**…**	**M&A35**	**M&A36**	**M&A37**
C1	I	MI	VI	…	I	VI	MI
C2	MI	MI	VI	…	I	VI	I
C3	MI	MI	VI	…	U	VI	I
C4	MI	MI	VI	…	U	VI	I
C5	I	I	VI	…	MI	I	VI
C6	I	I	VI	…	VI	VI	VI
C7	I	MI	VI	…	U	VI	VI
C8	MI	U	VI	…	U	VI	VI
…	…	…	…	…	…	…	…
C25	I	I	VI	…	I	I	VI
C26	I	MI	VI	…	VI	VI	I
C27	I	U	VI	…	VI	I	VI
C28	I	MI	VI	…	I	VI	VI

Table 5-32: Fuzzy number and average fuzzy weight for the factors from managers and administrators' perspectives in Hospital B

	M&A1	**M&A35**	**…**	**M&A37**	Average Fuzzy weighting	Crisp value
C1	(0.5,0.75,1)	(0.25,0.5,0.75)	…	(0.25,0.5,0.75)	(0.49,0.74,0.92)	0.7162
C2	(0.25,0.5,0.75)	(0.25,0.5,0.75)	…	(0.5,0.75,1)	(0.46,0.70,0.89)	0.6847
C3	(0.25,0.5,0.75)	(0.25,0.5,0.75)	…	(0.5,0.75,1)	(0.47,0.72,0.91)	0.7027
C4	(0.25,0.5,0.75)	(0.25,0.5,0.75)	…	(0.5,0.75,1)	(0.49,0.74,0.92)	0.7185
C5	(0.5,0.75,1)	(0.5,0.75,1)	…	(0.75,1,1)	(0.52,0.76,0.91)	0.7275
C6	(0.5,0.75,1)	(0.5,0.75,1)	…	(0.75,1,1)	(0.47,0.70,0.86)	0.6734
C7	(0.5,0.75,1)	(0.25,0.5,0.75)	…	(0.75,1,1)	(0.45,0.70,0.88)	0.6757
C8	(0.25,0.5,0.75)	(0,0.25,0.5)	…	(0.75,1,1)	(0.38,0.61,0.82)	0.6059
…	…	…	…	…	…	…
C25	(0.5,0.75,1)	(0.5,0.75,1)	…	(0.75,1,1)	(0.37,0.62,0.81)	0.6014
C26	(0.5,0.75,1)	(0.25,0.5,0.75)	…	(0.5,0.75,1)	(0.59,0.83,0.94)	0.7860
C27	(0.5,0.75,1)	(0,0.25,0.5)	…	(0.75,1,1)	(0.59,0.83,0.93)	0.7815
C28	(0.5,0.75,1)	(0.25,0.5,0.75)	…	(0.75,1,1)	(0.57,0.81,0.95)	0.7748

Additionally, the average distance between expert fuzzy number and the average fuzzy number to measure the experts' consensus and agreement level were calculated using Eq.(42) and Eq.(43) respectively. In order to test each criterion in respect to the conditions defined in section 4.2.1.3 to decide whether to retain or remove the criterion. Table 5-33, Table 5-34, Table 5-35, and Table 5-36 demonstrates the result of each group.

Table 5-33: Experts' result for the three conditions and the final decision in Hospital B

Evaluation factor	d-value	% group agreement	Factor importa nce	Verdict
Urgency (C1)	0.1570	67%	0.6528	**Retain**
Impact/effectiveness (C2)	0.0898	50%	0.7361	Remove
Importance/significance (C3)	0.1351	67%	0.6944	**Retain**
Strategic alignment (C4)	0.1612	17%	0.7222	Remove
Critical to quality (C5)	0.1226	67%	0.7639	**Retain**
Competitive advantage (C6)	0.1981	50%	0.6111	Remove
Sustainability (C7)	0.1226	67%	0.7639	**Retain**
Replicability (C8)	0.2039	33%	0.6806	Remove
Evidence based (C9)	0.1021	83%	0.8333	**Retain**
Creativity and Innovation (C10)	0.0898	50%	0.7361	Remove
Top management commitment (C11)	0.0907	83%	0.8611	**Retain**
Learning and growth potential (C12)	0.1570	67%	0.6528	**Retain**
Conformance to contract or accreditation requirements (C13)	0.1570	67%	0.6528	**Retain**
Risks (C14)	0.1539	50%	0.6944	Remove
Legal implications (C15)	0.1729	33%	0.7222	Remove
Ethical implications (C16)	0.0898	50%	0.7361	Remove
Improvement duration/ Time (C17)	0.1203	67%	0.5694	Remove
Resource and information availability (C18)	0.1422	67%	0.8194	**Retain**
Cost (C19)	0.1226	67%	0.7639	**Retain**
Ease of implementation (C20)	0.2291	33%	0.6389	Remove
Regulatory compliance (C21)	0.0898	50%	0.7361	Remove
Employee empowerment (C22)	0.1612	17%	0.7222	Remove
ROI (C23)	0.0694	67%	0.7083	**Retain**
Cost reduction (C24)	0.1667	67%	0.5833	Remove
Profit (C25)	0.1894	50%	0.6528	Remove
Patients satisfaction (C26)	0.0898	50%	0.7361	Remove
Health and safety (C27)	0.1226	67%	0.7639	**Retain**
Reputational image (C28)	0.0567	83%	0.7778	**Retain**

Table 5-34: Physicians' result for the three conditions and the final decision in Hospital B

Evaluation factor	d-value	% group agreement	Factor importance	Verdict
Urgency (C1)	0.1478	84%	0.5677	Remove
Impact/effectiveness (C2)	0.1492	88%	0.6432	Remove
Importance/significance (C3)	0.1662	81%	0.6250	Remove
Strategic alignment (C4)	0.1724	75%	0.5651	Remove
Critical to quality (C5)	0.1540	84%	0.6016	Remove
Competitive advantage (C6)	0.1580	84%	0.6328	Remove
Sustainability (C7)	0.1705	78%	0.6276	Remove
Replicability (C8)	0.1655	75%	0.6120	Remove
Evidence based (C9)	0.1650	81%	0.6536	**Retain**
Creativity and Innovation (C10)	0.1866	75%	0.6016	Remove
Top management commitment (C11)	0.1850	72%	0.6120	Remove
Learning and growth potential (C12)	0.1751	78%	0.5885	Remove
Conformance to contract or accreditation requirements (C13)	0.1525	88%	0.6198	Remove
Risks (C14)	0.1810	72%	0.6094	Remove
Legal implications (C15)	0.1739	75%	0.5781	Remove
Ethical implications (C16)	0.1893	72%	0.6198	Remove
Improvement duration/ Time (C17)	0.1460	88%	0.5703	Remove
Resource and information availability (C18)	0.1612	81%	0.6510	**Retain**
Cost (C19)	0.1715	78%	0.6146	Remove
Ease of implementation (C20)	0.1536	84%	0.5755	Remove
Regulatory compliance (C21)	0.1564	84%	0.6094	Remove
Employee empowerment (C22)	0.1974	69%	0.6198	Remove
ROI (C23)	0.1381	94%	0.6146	Remove
Cost reduction (C24)	0.1401	91%	0.5911	Remove
Profit (C25)	0.1338	94%	0.5990	Remove
Patients satisfaction (C26)	0.1887	66%	0.6667	**Retain**
Health and safety (C27)	0.1941	63%	0.6771	**Retain**
Reputational image (C28)	0.1776	75%	0.6354	Remove

Table 5-35: Nurses' result for the three conditions and the final decision in Hospital B

Evaluation factor	d-value	% group agreement	Factor importa nce	Verdict
Urgency (C1)	0.1810	75%	0.6052	Remove
Impact/effectiveness (C2)	0.1548	86%	0.6071	Remove
Importance/significance (C3)	0.1483	89%	0.6131	Remove
Strategic alignment (C4)	0.1274	101%	0.6052	Remove
Critical to quality (C5)	0.1409	92%	0.5853	Remove
Competitive advantage (C6)	0.1546	86%	0.6032	Remove
Sustainability (C7)	0.1537	88%	0.5952	Remove
Replicability (C8)	0.1518	81%	0.5734	Remove
Evidence based (C9)	0.1591	86%	0.6151	Remove
Creativity and Innovation (C10)	0.1741	46%	0.5496	Remove
Top management commitment (C11)	0.1751	82%	0.6131	Remove
Learning and growth potential (C12)	0.1751	82%	0.6151	Remove
Conformance to contract or accreditation requirements (C13)	0.1475	93%	0.6091	Remove
Risks (C14)	0.1682	82%	0.5694	Remove
Legal implications (C15)	0.1791	75%	0.5913	Remove
Ethical implications (C16)	0.1575	85%	0.5972	Remove
Improvement duration/ Time (C17)	0.1202	88%	0.5516	Remove
Resource and information availability (C18)	0.1431	93%	0.6091	Remove
Cost (C19)	0.1316	90%	0.5675	Remove
Ease of implementation (C20)	0.1561	87%	0.5913	Remove
Regulatory compliance (C21)	0.1410	90%	0.5734	Remove
Employee empowerment (C22)	0.1947	76%	0.5595	Remove
ROI (C23)	0.1134	70%	0.5456	Remove
Cost reduction (C24)	0.1253	59%	0.5179	Remove
Profit (C25)	0.0968	71%	0.5337	Remove
Patients satisfaction (C26)	0.1680	82%	0.6290	Remove
Health and safety (C27)	0.1734	73%	0.6548	**Retain**
Reputational image (C28)	0.1689	78%	0.6409	Remove

Table 5-36: Managers and administrators' result for the three conditions and the final decision in Hospital B

Evaluation factor	d-value	% group agreement	Factor importa nce	Verdict
Urgency (C1)	0.1512	46%	0.7162	Remove
Impact/effectiveness (C2)	0.1770	68%	0.6847	**Retain**
Importance/significance (C3)	0.1534	43%	0.7027	Remove
Strategic alignment (C4)	0.1555	41%	0.7185	Remove
Critical to quality (C5)	0.1852	32%	0.7275	Remove
Competitive advantage (C6)	0.2177	57%	0.6734	Remove
Sustainability (C7)	0.1861	68%	0.6757	**Retain**
Replicability (C8)	0.2028	65%	0.6059	Remove
Evidence based (C9)	0.0000	0%	0.0000	Remove
Creativity and Innovation (C10)	0.1683	73%	0.6824	**Retain**
Top management commitment (C11)	0.1828	38%	0.7050	Remove
Learning and growth potential (C12)	0.1668	46%	0.7050	Remove
Conformance to contract or accreditation requirements (C13)	0.2167	51%	0.6914	Remove
Risks (C14)	0.2051	65%	0.6599	Remove
Legal implications (C15)	0.2167	51%	0.6914	Remove
Ethical implications (C16)	0.2170	24%	0.6959	Remove
Improvement duration/ Time (C17)	0.1951	24%	0.7230	Remove
Resource and information availability (C18)	0.1880	73%	0.7387	**Retain**
Cost (C19)	0.2178	19%	0.7185	Remove
Ease of implementation (C20)	0.2011	57%	0.6869	Remove
Regulatory compliance (C21)	0.1637	35%	0.7275	Remove
Employee empowerment (C22)	0.1507	76%	0.7410	**Retain**
ROI (C23)	0.2000	54%	0.6937	Remove
Cost reduction (C24)	0.1709	78%	0.6059	Remove
Profit (C25)	0.2070	59%	0.6014	Remove
Patients satisfaction (C26)	0.1658	84%	0.7860	**Retain**
Health and safety (C27)	0.1831	81%	0.7815	**Retain**
Reputational image (C28)	0.1518	86%	0.7748	**Retain**

Table 5-37 demonstrates the retained factors from each group. Consequently, Venn diagram in Figure 5-3 clarifies the common factors between the groups, where a factor considered to be a critical factor if it had been selected by two or more groups. Finally, Table 5-38 illustrates the result of the calculation of the total weight for the critical factors.

Table 5-37: Retained factors from each group in Hospital B.

Experts	Doctors and Physicians	Nurses	Managers and Administrators
Top management commitment	Health and safety	Health and safety	Patients satisfaction
Evidence based	Patients satisfaction		Health and safety
Resource and information availability	Creativity and Innovation		Reputational image
Reputational image	Resource availability		Employee empowerment
Cost			Resource and information availability
Sustainability			Impact
Critical to quality			Creativity and Innovation
Health and safety			Sustainability
ROI			
Significant			
Learning and growth potential			
Contract or accreditation requirements			

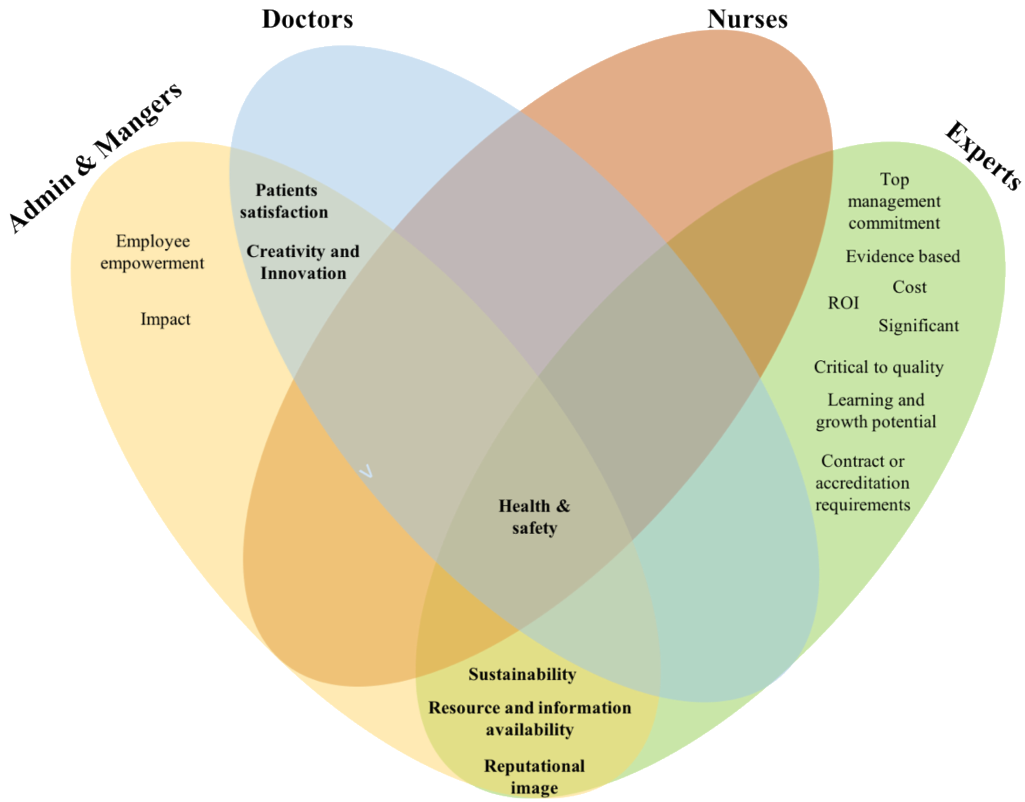


Figure 5-3: Venn Diagram for selected factors of the four groups.

Table 5-38: Factors selected for hospital B

Ranking	Evaluation factors	Fuzzy weight for the selected factor	Total weight's crisp value
1	Health and safety	[0.50,0.75,0.91]	0.72
2	Reputational image	[0.48,0.72,0.92]	0.71
3	Resource and information availability	[0.48,0.73,0.90]	0.70
4	Patient satisfaction	[0.48,0.73,0.91]	0.70
5	Sustainability	[0.43,0.68,0.88]	0.67
6	Creativity and innovation	[0.41,0.65,0.87]	0.64

5.5 FIS Preparedness

In order to construct the membership function, knowledge was sought from fourteen experts. HE-k was assigned for each expert, where HE stands for Healthcare Expert and k for the expert number. All of the experts from the healthcare authority cooperate office, since they deal with projects and management on a daily basis and they were chosen to have different backgrounds to get various point of views. The expert's occupation and experience are described below:

- HE-1: Chief Clinical Officer with 12 years of experience in healthcare, M.S. in healthcare management
- HE-2: Excellence &Innovation Manager with 18 years of experience in healthcare, Ph.D. candidate in Healthcare Management
- HE-3: Senior clinical system analyst & physician with 17 years of experience in healthcare.
- HE-4: Quality director & physician with 10 years of experience in healthcare.
- HE-5: Quality officer & dental assistance with 9 years of experience in healthcare.
- HE-6: Clinical service manager & physician with 27 years of experience in healthcare.
- HE-7: Senior safety officer with 20 years of experience in healthcare.
- HE-8: Risk officer with more than 6 years of experience in healthcare
- HE-9: Safety officer & nurse with 14 years of experience in healthcare

- HE-10: Senior Quality officer & physician with 10 years of experience in healthcare
- HE-11: Quality officer with 6 years of experience in healthcare
- HE-12: Senior safety officer with 20 years of experience in healthcare
- HE-13: Senior performance officer with 11 years of experience in healthcare
- HE-14: Healthcare consultant & physician with 34 years of experience in healthcare.

5.5.1 Results of expert knowledge acquisition

Subject matter experts quantified the linguistic terms associated with each criterion using an indirect interval estimation to construct membership functions. Each expert was asked to assign one of five linguistic terms for each of the ten criteria: “Very low”, “Low”, “Moderate”, “High”, and “Very High”. They chose from three linguistic terms for improvement classification: “Weakly preferred”, “Moderately preferred”, and “Strongly preferred”. They used ranges between 0 and 100, providing 53 intervals from each expert and a total of 742 intervals.

Table 5-39 contains the experts’ quantification for patient’s satisfaction subset intervals. Variation among all intervals can be observed and that explain the overlap between the different intervals. A trapezoidal membership function (Figure 5-4) was structured according to the data in Table 5-39. Note that all the values were divided by 100 to convert the numbers into ratios. The upper value for the “Very Low” class interval is 0.35 and the interval core is between [0,0.05]. The “Low” interval is between [0.06, 0.7] where the core exists between [0.2,0.4] with the lower boundary between 0.4 and 0.7. The “Moderate” class overlaps with the “Low” class between

[0.2, 0.4] and the "High" class between [0.7,0.85]. The support of the "High" starts at 0.4 and ends at 0.97, while the" Very High" class support is between [0.6,1]. The core structures of the low, moderate and high classes are almost similar and are wide when compared to the Very Low and Very High classes.

Table 5-39: Interval assignment for patient's satisfaction

Linguistic terms / Experts	**Very Low**		**Low**		**Moderate**		**High**		**Very High**	
	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value
HE-1	**0**	30	30	60	60	70	70	80	80	**100**
HE-2	**0**	10	10	50	50	85	85	90	90	**100**
HE-3	**0**	10	10	30	30	40	40	60	60	**100**
HE-4	**0**	30	30	40	40	50	50	80	80	**100**
HE-5	**0**	35	35	50	50	80	80	95	95	**100**
HE-6	**0**	30	30	50	50	60	60	85	85	**100**
HE-7	**0**	10	10	55	56	60	70	75	80	**100**
HE-8	**0**	15	15	20	20	60	60	80	80	**100**
HE-9	**0**	20	20	50	50	85	85	90	90	**100**
HE-10	**0**	35	40	59	60	79	80	97	98	**100**
HE-11	**0**	20	21	40	41	60	61	80	81	**100**
HE-12	**0**	35	35	70	70	84	85	89	90	**100**
HE-13	**0**	5	6	49	50	64	85	94	95	**100**
HE-14	**0**	10	10	50	50	85	85	90	90	**100**

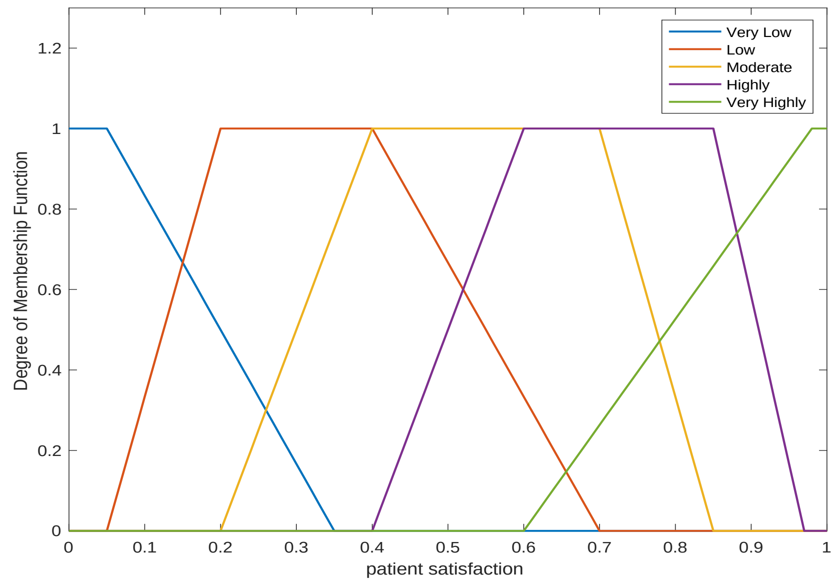


Figure 5-4: Patient’s satisfaction membership function

Table 5-40 contains experts’ assessments for health and safety’s linguistic class intervals. It can be observed that the values are large, even for the lower classes. The “Very Low” class has an upper bound of 0.2, in which denotes 100% expert agreement for the class core. The maximum value for the very low class is 0.7, which is considered to be high. The “Low” class support is between 0.2 and 0.8, the core exists between 0.4 and 0.75. Whereas the support of the “Moderate” class interval assigned values between [0.4, 0.9] and the core between 0.85 and 0.9. For the “High” linguistics class the experts assigned [0.7, 0.98] for the support, [0.85,0.9] for the core, [0.7,0.85] for the left boundary, and [0.9,0.98] for the right boundary. The “Very High” class intervals overlaps the high class with [0.85,0.99]. It was observed that the core structures of the lower classes; Very low and Low; are large and employed 70% of the membership function, whilst the other three classes cores are small. This yielded to a right skewed membership function in Figure 5-5 and it indicates the importance of the health and safety in healthcare environment.

Table 5-40: Interval assignment for health and safety

Experts \ Linguistic terms	**Very Low**		**Low**		**Moderate**		**High**		**Very High**	
	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value
HE-1	**0**	40	40	80	80	90	90	95	95	**100**
HE-2	**0**	30	30	50	50	85	85	90	90	**100**
HE-3	**0**	30	30	50	50	70	70	90	90	**100**
HE-4	**0**	30	30	50	50	70	70	90	90	**100**
HE-5	**0**	50	51	79	80	89	90	98	99	**100**
HE-6	**0**	40	40	50	50	70	70	90	90	**100**
HE-7	**0**	50	50	70	85	80	88	89	90	**100**
HE-8	**0**	30	30	40	40	70	70	85	85	**100**
HE-9	**0**	20	20	60	60	80	80	95	95	**100**
HE-10	**0**	50	51	79	80	89	90	98	99	**100**
HE-11	**0**	50	51	60	61	75	76	95	96	**100**
HE-12	**0**	70	75	80	81	85	86	98	99	**100**
HE-13	**0**	30	30	49	50	75	76	90	91	**100**
HE-14	**0**	30	30	60	60	85	85	90	90	**100**

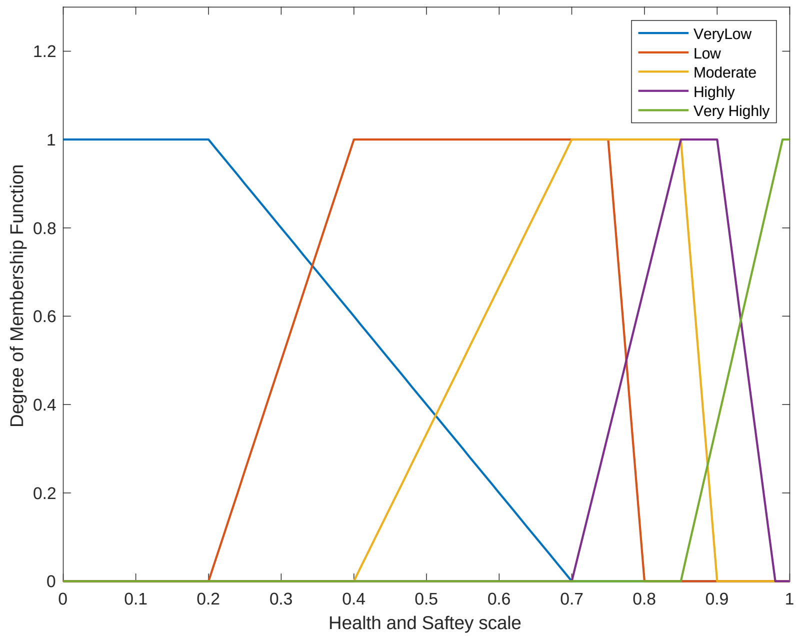


Figure 5-5: Health and Safety membership function

Table 5-41 details the linguistic class and corresponding intervals for the reputational image criterion, and its membership function is depicted in Figure 5-6. The “Low” class core occurs between 0 and 0.1, with the boundaries at 0 and 0.15. The “Very Low” class core lies between 0.25 and 0.55, while the boundaries at 0.1 and 0.7. The “Moderate” class boundaries appear between 0.25 and 0.85, with a core area of [0.5,0.71]. Whereas the upper boundaries and the lower boundaries of the “High” linguistic class interval are [0.5,0.7] and [0.85, 0.95] respectively and the core lies between both boundaries at 0.7 and 0.85. The “Very High” class reaches the full membership function between 0.96 and 1 and membership function at [0.7,0.96]. The shape of membership function is comparable to the patient’s satisfaction membership function. It is apparent that the “Low” and Very High” class have small core areas and the middle classes overlapped and have the widest core areas.

Table 5-41: Interval assignment for reputational image

Experts \ Linguistic Terms	Very Low		Low		Moderate		High		Very High	
	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value
HE-1	**0**	20	20	40	40	60	60	80	80	**100**
HE-2	**0**	10	10	50	50	85	85	90	90	**100**
HE-3	**0**	20	20	30	30	50	50	70	70	**100**
HE-4	**0**	30	30	50	50	70	70	90	90	**100**
HE-5	**0**	50	51	70	71	80	81	95	96	**100**
HE-6	**0**	50	50	60	60	70	70	80	80	**100**
HE-7	**0**	39	40	64	65	79	80	84	85	**100**
HE-8	**0**	20	20	25	25	50	50	75	75	**100**
HE-9	**0**	30	30	50	50	80	80	90	90	**100**
HE-10	**0**	50	50	60	60	70	70	80	80	**100**
HE-11	**0**	50	51	60	61	75	76	95	96	**100**
HE-12	**0**	50	55	65	70	80	85	90	91	**100**
HE-13	**0**	10	11	30	31	50	51	80	81	**100**
HE-14	**0**	30	30	60	60	85	85	90	90	**100**

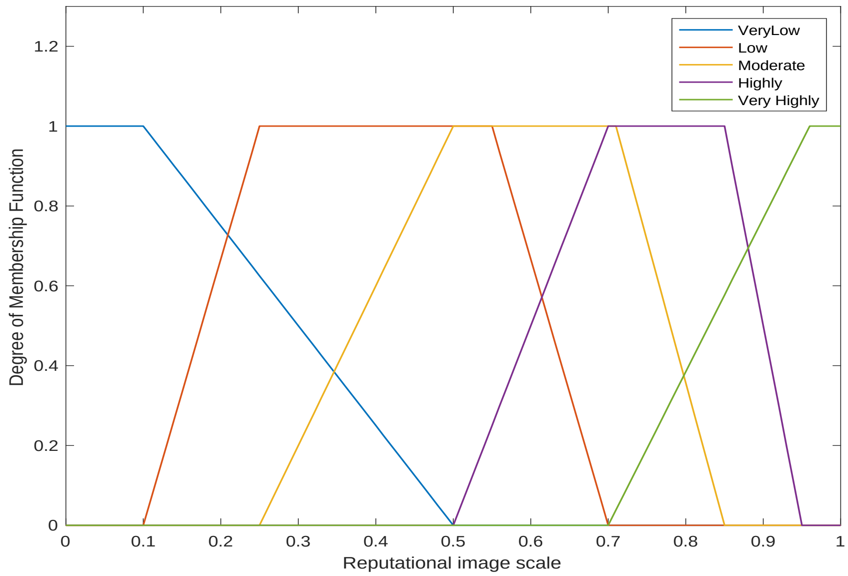


Figure 5-6: Reputational image membership function.

The sustainability linguistic class interval evaluation is demonstrated in Table 5-42. Even though the “Very Low” class core structure is between 0,1 with 100% expert’s agreement on that the upper boundary is between 0.1 and 0.6. The previous interval overlaps with the other classes; Low, moderate, and high, denotate that experts varied in interval assignment between 0.1 and 0.6. The “Low” class has a support of [0.1,0.7], while the moderate, high and very high class bounded by [0.31, 0.85], [0.5, 0.94], and [0.8, 1] respectively. The low and the moderate classes has the largest core structure whereas high and very high have almost the same sized core structure. Figure 5-7 illustrates the sustainability trapezoidal Membership function.

Table 5-42: Interval assignment for sustainability

Experts \ Linguistic terms	Very Low		Low		Moderate		High		Very High	
	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value
HE-1	**0**	10	10	50	50	85	85	90	90	**100**
HE-2	**0**	10	10	50	50	85	85	90	90	**100**
HE-3	**0**	30	30	50	50	70	70	80	80	**100**
HE-4	**0**	30	30	50	50	70	70	90	90	**100**
HE-5	**0**	39	40	59	60	69	70	89	90	**100**
HE-6	**0**	60	60	70	70	80	80	90	90	**100**
HE-7	**0**	39	40	54	55	69	70	79	80	**100**
HE-8	**0**	20	20	35	35	65	65	80	80	**100**
HE-9	**0**	10	10	50	50	85	85	94	94	**100**
HE-10	**0**	59	60	60	70	70	80	80	90	**100**
HE-11	**0**	35	36	40	41	70	71	85	85	**100**
HE-12	**0**	15	20	35	40	60	65	90	95	**100**
HE-13	**0**	10	11	30	31	50	51	80	81	**100**
HE-14	**0**	10	10	50	50	85	85	90	90	**100**

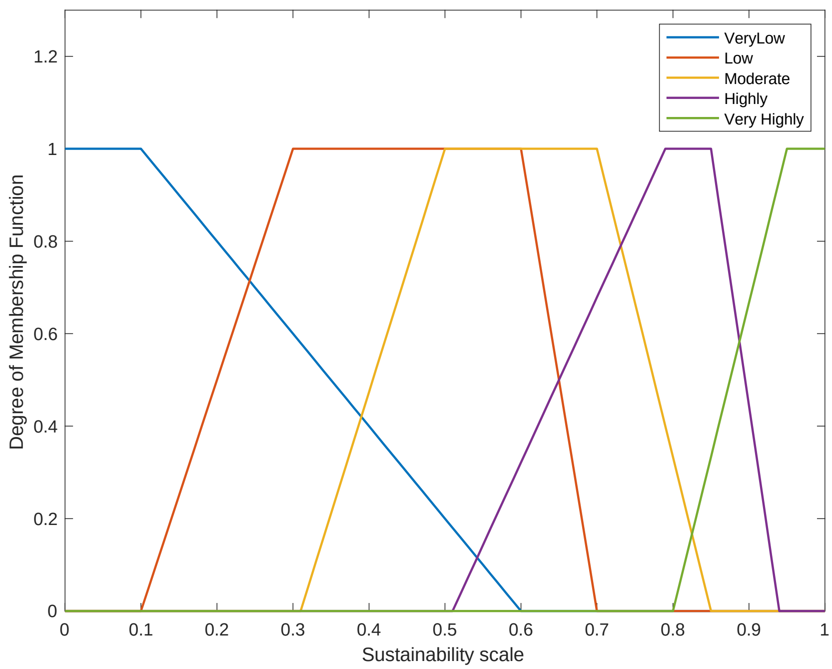


Figure 5-7: Sustainability membership function

The resource and information availability membership function in Figure 5-8 was constructed based on the data from Table 5-43. The membership function shows a lower variation and lower overlap area compared to the previous membership functions. With a very small core, “Very Low” class upper boundaries lie between [0.05,0.49] and the “Low” class is bounded by 0.06 and 0.6, which illustrates a large overlap of almost 0.5 between both classes. The “Moderate” and the “High” class intervals have almost the same size of core structure of [0.6, 0.7] and [0.8, 0.88], respectively. With the smallest core area, inputs considered to be Very high if its value between [0.95,1].

Table 5-43: Interval assignment for resource and information availability

Experts \ Linguistic terms	**Very Low**		**Low**		**Moderate**		**High**		**Very High**	
	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value
HE-1	**0**	20	20	30	30	70	70	90	90	**100**
HE-2	**0**	10	10	50	50	85	85	90	90	**100**
HE-3	**0**	30	30	60	60	80	80	90	90	**100**
HE-4	**0**	20	20	50	50	70	70	90	90	**100**
HE-5	**0**	39	40	59	60	69	70	89	90	**100**
HE-6	**0**	20	20	40	40	60	60	80	80	**100**
HE-7	**0**	9	15	40	70	80	88	90	90	**100**
HE-8	**0**	10	10	50	50	85	85	90	90	**100**
HE-9	**0**	10	10	40	40	80	80	94	95	**100**
HE-10	**0**	49	50	59	60	69	70	89	90	**100**
HE-11	**0**	20	21	40	41	60	61	80	81	**100**
HE-12	**0**	39	40	59	60	84	85	94	95	**100**
HE-13	**0**	5	6	49	50	84	85	94	95	**100**
HE-14	**0**	10	10	50	50	85	85	90	90	**100**

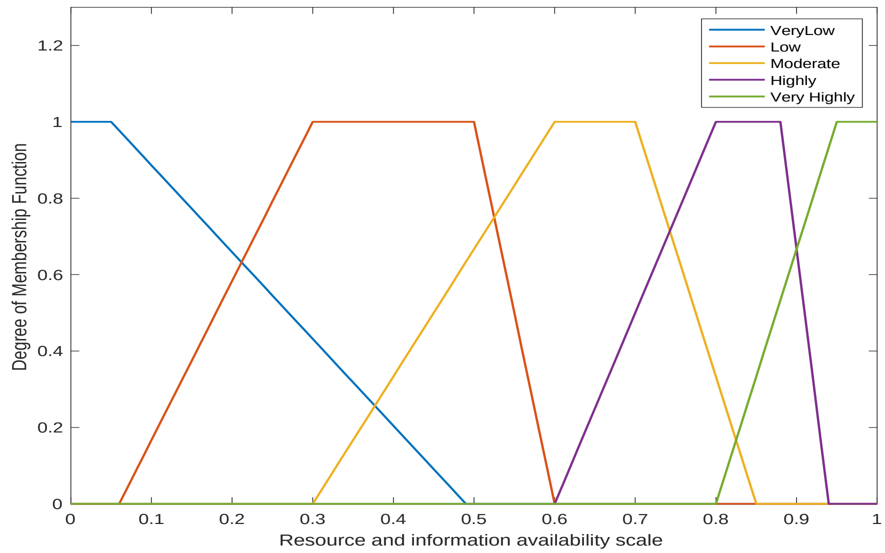


Figure 5-8: Resource and information availability membership function

The top management commitment membership function shown in Figure 5-9, created from experts' evaluations for top management commitment presented in Table 5-44, appears to be a mixed membership function both triangular and trapezoidal. The "Very High", "High" and the "Moderate" intervals class occupy the higher part of the graph, with supports areas of [0.5, 0.89], [0.6, 0.94], and [0.8, 1], respectively. The "Low" class has a triangular shape function tipped at 0.5, with a support area of [0.06, 0.74] while the "Very Low" class is bounded by [0,0.49], with a small core structure of 0.05 and wide upper boundary of 0.45.

Table 5-44: Interval assignment for top management commitment

Experts \ Linguistic terms	Very Low		Low		Moderate		High		Very High	
	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value
HE-1	**0**	30	30	50	50	70	70	85	85	**100**
HE-2	**0**	10	10	50	50	85	85	90	90	**100**
HE-3	**0**	30	30	50	50	60	60	80	80	**100**
HE-4	**0**	40	40	60	60	70	70	90	90	**100**
HE-5	**0**	39	40	59	60	69	70	89	90	**100**
HE-6	**0**	50	50	60	60	70	70	80	80	**100**
HE-7	**0**	49	50	74	75	89	90	94	95	**100**
HE-8	**0**	15	15	50	50	60	60	86	85	**100**
HE-9	**0**	40	40	60	60	80	80	94	94	**100**
HE-10	**0**	49	50	59	60	70	70	89	90	**100**
HE-11	**0**	45	46	50	51	70	71	87	88	**100**
HE-12	**0**	40	50	60	65	85	85	90	95	**100**
HE-13	**0**	5	6	49	50	84	85	94	95	**100**
HE-14	**0**	10	10	50	50	80	80	90	90	**100**

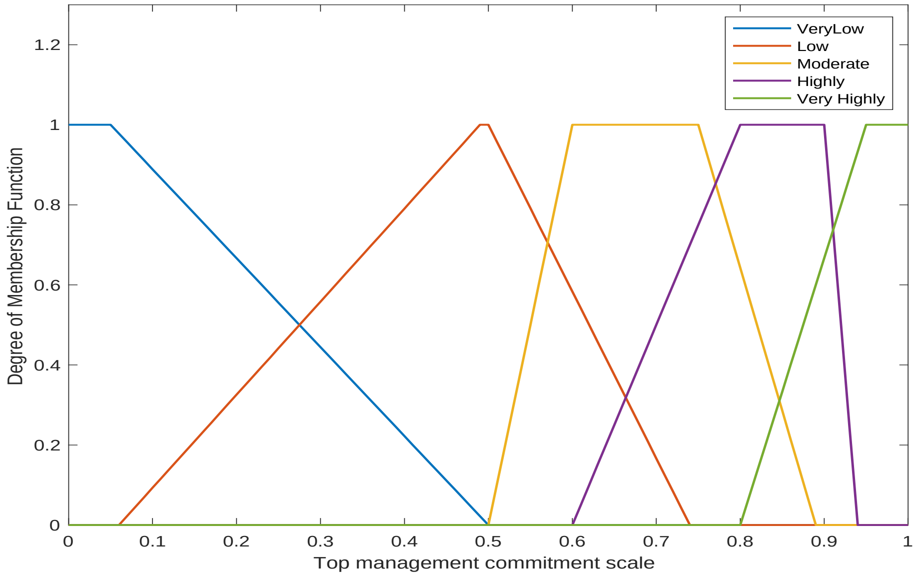


Figure 5-9: Top management commitment membership function

The evidence-based criterion is represented by a trapezoidal membership function as well, as shown in Figure 5-10. There is an obvious variation among experts' assessment for the criterion intervals classes (Table 5-45), especially in the "Low", "Moderate", and "High" classes. The core areas of these classes intersect as the core areas are [0.44, 0.51], [0.5, 0.8] and [0.6, 0.9], respectively. The other two classes; "Very Low" and "Very High," overlap other classes in their boundaries of [0.05, 0.5] and [0.6, 0.96], respectively. The membership has a full membership function only at "Very Low" and "Very High" core areas.

Table 5-45: Interval assignment for evidence-based criterion

Experts \ Linguistic terms	Very Low		Low		Moderate		High		Very High	
	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value
HE-1	**0**	40	40	70	70	90	90	95	95	**100**
HE-2	**0**	10	10	50	50	85	85	90	90	**100**
HE-3	**0**	20	20	40	40	50	50	60	60	**100**
HE-4	**0**	30	30	50	50	70	70	90	90	**100**
HE-5	**0**	50	51	70	71	80	81	95	96	**100**
HE-6	**0**	40	40	60	60	70	70	80	80	**100**
HE-7	**0**	39	40	64	65	79	80	89	90	**100**
HE-8	**0**	10	10	40	40	70	70	75	75	**100**
HE-9	**0**	30	30	60	60	80	80	94	94	**100**
HE-10	**0**	39	40	49	50	59	60	69	70	**100**
HE-11	**0**	30	31	40	41	50	51	80	81	**100**
HE-12	**0**	30	35	50	55	75	80	90	95	**100**
HE-13	**0**	5	6	49	80	84	85	94	95	**100**
HE-14	**0**	30	30	50	50	80	85	85	90	**100**

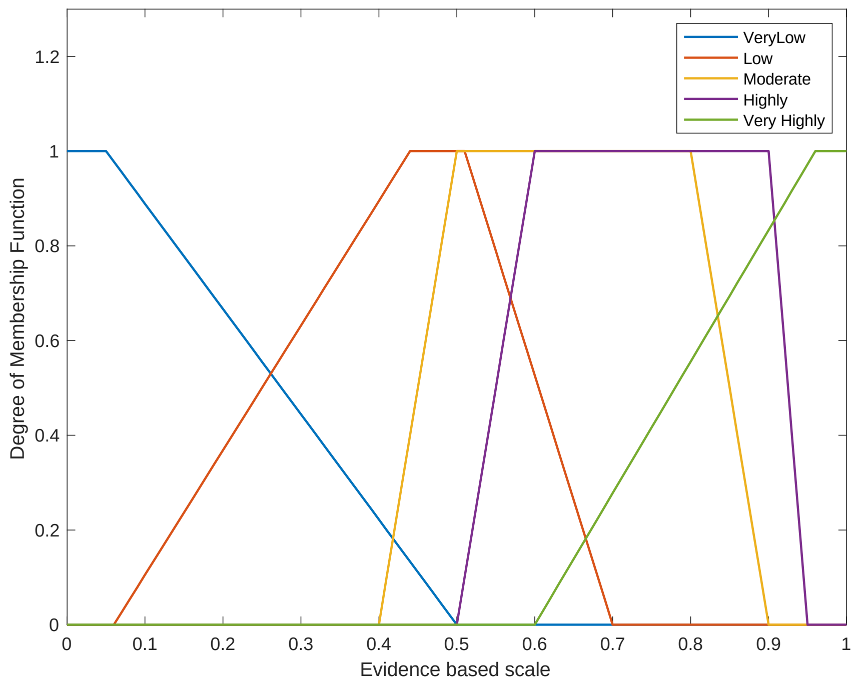


Figure 5-10: Evidence based membership function.

Table 5-46 shows a noticeable variation in the upper and lower value of the first three classes and more and reasonable agreement in the last two classes. A trapezoidal function was created based on the data from Table 5-46 and is presented in Figure 5-11. Note that the core areas of the membership don't overlap. Critical to quality was considered to be "Moderate" if the input was between [0.6, 0.8], making its core the largest. It is bounded by 0.4 and 0.89. The "Very Low" and the "Very High" classes had the smallest core structure, with [0, 0.05] and [0.99, 1]. The "Low" and the "High" intervals classes existed between the intervals of [0.06, 0.79], and [0.6, 0.98], respectively.

Table 5-46: Interval assignment for critical to quality

Experts \ Linguistic terms	Very Low		Low		Moderate		High		Very High	
	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value
HE-1	**0**	30	30	60	60	80	80	90	90	**100**
HE-2	**0**	10	10	50	50	85	85	90	90	**100**
HE-3	**0**	20	20	40	40	60	60	80	80	**100**
HE-4	**0**	20	20	50	50	70	70	90	90	**100**
HE-5	**0**	50	51	79	80	89	90	98	99	**100**
HE-6	**0**	50	50	60	60	70	70	90	90	**100**
HE-7	**0**	39	40	74	75	89	90	94	95	**100**
HE-8	**0**	15	15	45	45	80	80	90	90	**100**
HE-9	**0**	20	20	50	50	80	80	94	94	**100**
HE-10	**0**	39	40	59	60	79	80	97	98	**100**
HE-11	**0**	45	46	50	51	75	76	86	87	**100**
HE-12	**0**	25	30	45	50	70	75	85	90	**100**
HE-13	**0**	5	6	49	50	84	85	94	95	**100**
HE-14	**0**	30	30	50	50	75	75	85	90	**100**

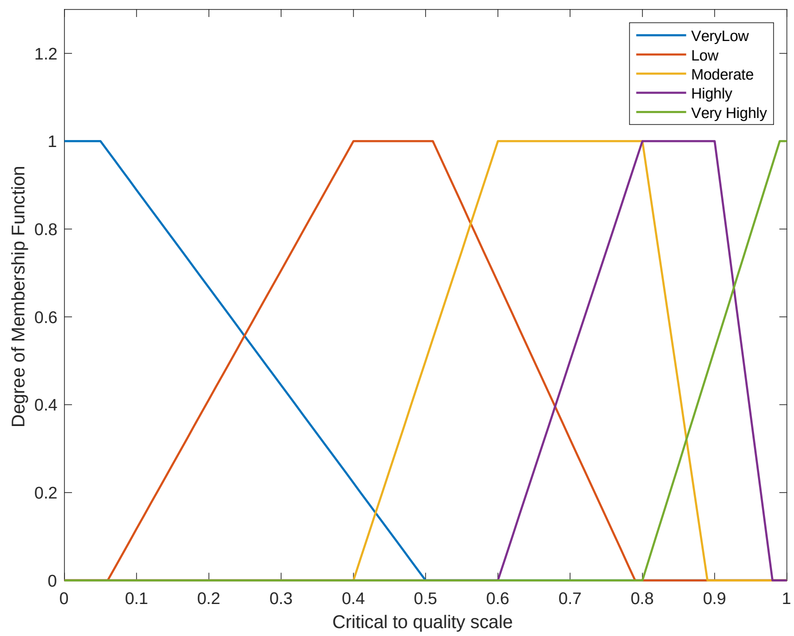


Figure 5-11: Critical to quality membership function

Table 5-47 contains experts' evaluation for the ethical implications linguistic intervals class. Its membership function in Figure 5-12 depicts the overlap between the different classes. In this figure, the boundaries for the "Very Low" class exist between 0 and 0.4, with a core area of [0, 0.1] interval. The "Low" class has boundaries of [0.1, 0.7], and its core exists between [0.3, 0.4]. In addition, the boundaries of the "Moderate", "High", "Very high" are [0.31, 0.9], [0.45, 0.95], and [0.6, 1], respectively, and their cores areas defined between [0.45, 0.7], [0.6, 0.9], and [0.95, 1], respectively. The membership function demonstrates uniformity between the intervals.

Table 5-47: Interval assignment for ethical implications

Experts \ Linguistic terms	Very Low		Low		Moderate		High		Very High	
	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value
HE-1	**0**	40	40	70	70	90	90	95	95	**100**
HE-2	**0**	10	10	50	50	85	85	90	90	**100**
HE-3	**0**	40	40	50	50	70	70	90	90	**100**
HE-4	**0**	30	30	50	50	70	70	90	90	**100**
HE-5	**0**	39	40	59	60	69	70	89	90	**100**
HE-6	**0**	30	30	50	50	60	60	80	80	**100**
HE-7	**0**	39	40	59	60	79	80	89	90	**100**
HE-8	**0**	15	15	40	40	45	45	60	60	**100**
HE-9	**0**	30	30	50	50	85	85	94	94	**100**
HE-10	**0**	20	21	54	60	79	70	89	90	**100**
HE-11	**0**	30	31	40	41	60	61	85	86	**100**
HE-12	**0**	15	20	30	40	60	70	85	90	**100**
HE-13	**0**	10	11	30	31	50	51	80	81	**100**
HE-14	**0**	20	20	40	40	80	80	90	90	**100**

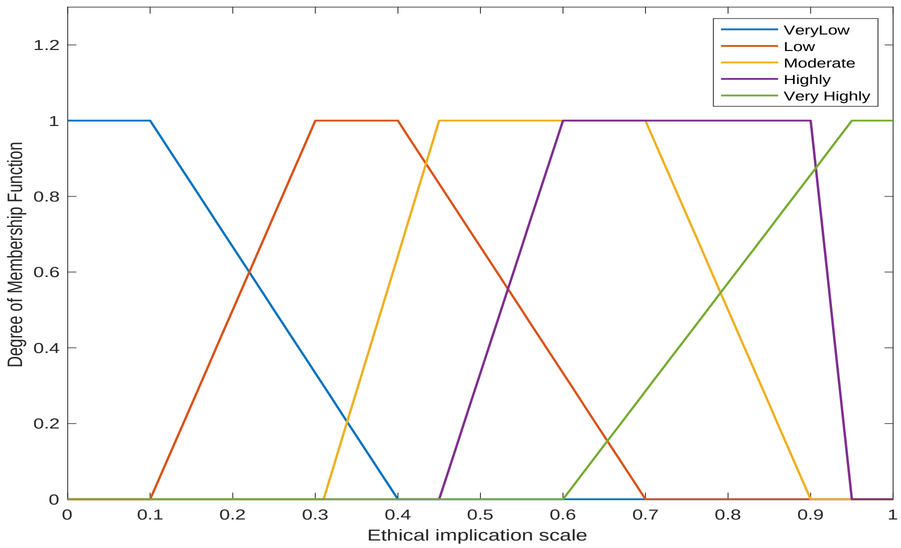


Figure 5-12: Ethical implication membership function

Figure 5-13 represents the trapezoidal membership function of the creativity and innovation criterion. The boundaries for each class overlap the core area of the adjacent class. The core structures of all classes are inconsistent. The “Very low” core begins at 0 and ends at 0.05, and is bounded by [0,0.39]. The “Low” class core exists between [0.2, 0.4], and the boundaries between [0.05, 0.6]. The “Moderate”, “High”, and “Very High” boundaries are between [0.21, 0.85], [0.5, 0.94], and [0.7, 1], respectively. The core structure for the three classes are between 0.5 and 0.6 for the Moderate, between 0.7 and 0.85 for the High and between 0.95 and 1 for the Very High class.

Table 5-48: Interval assignment for creativity and innovation

Experts \ Linguistic terms	Very Low		Low		Moderate		High		Very High	
	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value
HE-1	**0**	20	20	40	40	60	60	80	80	**100**
HE-2	**0**	10	10	50	50	85	85	90	90	**100**
HE-3	**0**	20	20	40	40	50	50	70	70	**100**
HE-4	**0**	20	20	50	50	70	70	90	90	**100**
HE-5	**0**	39	40	59	60	69	70	89	90	**100**
HE-6	**0**	30	30	60	60	70	70	80	80	**100**
HE-7	**0**	29	30	59	60	74	75	84	85	**100**
HE-8	**0**	5	5	40	40	50	50	70	70	**100**
HE-9	**0**	20	20	50	50	80	80	90	90	**100**
HE-10	**0**	5	6	50	51	60	61	70	71	**100**
HE-11	**0**	10	11	20	21	50	51	70	71	**100**
HE-12	**0**	20	25	40	45	70	75	89	90	**100**
HE-13	**0**	5	6	49	50	84	85	94	95	**100**
HE-14	**0**	20	20	50	50	80	80	85	90	**100**

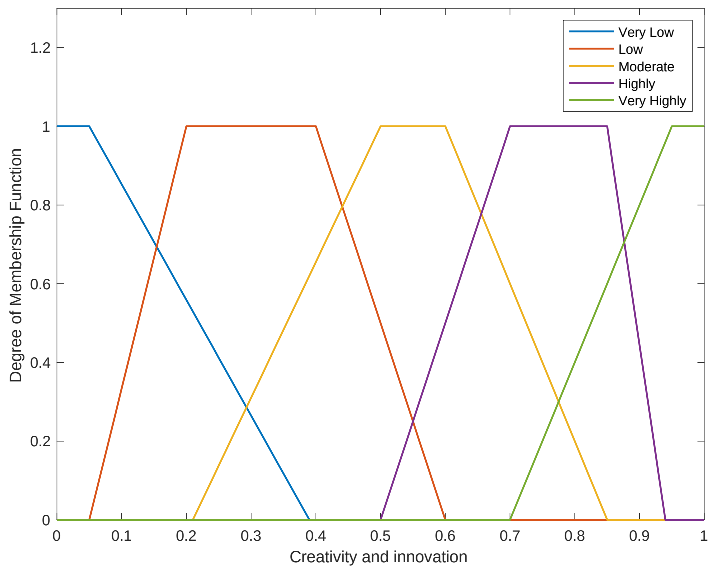


Figure 5-13: Creativity and innovation membership function

In addition to quantifying the linguistic classes associated with the criteria, the second question from the survey asked the experts to quantify three linguistic variables, which represents classification of improvement preference, including "Weakly Preferred", "Moderately Preferred", "Strongly Preferred." Figure 5-14 displays the assignment of intervals associated with improvement preferences. Figure 5-14 represents the Improvement classification membership function. The Weakly Preferred class core structure of the full membership function lies between 0 and 0.2, with boundaries of [0, 0.4]. The "Moderately Preferred" core structure exists between 0.4 and 0.5 with full a membership function, and the class lies between boundaries of 0.2 and 0.7. For the "Strongly Preferred" class the core structure exists between 0.75 and 1 and is bounded by 0.6 and 1. The Moderately Preferred core interval is the smallest of all the classes and the Strongly Preferred class has the largest core area.

Table 5-49: Interval assignment for improvement classification.

Experts \ Linguistic terms	Weakly Preferred		Moderately Preferred		Strongly Preferred	
	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value
HE-1	**0**	40	40	75	75	**100**
HE-2	**0**	30	30	65	65	**100**
HE-3	**0**	25	25	65	65	**100**
HE-4	**0**	20	20	60	60	**100**
HE-5	**0**	35	35	66	66	**100**
HE-6	**0**	21	21	75	75	**100**
HE-7	**0**	30	30	65	65	**100**
HE-8	**0**	30	30	60	60	**100**
HE-9	**0**	30	30	68	68	**100**
HE-10	**0**	35	35	70	70	**100**
HE-11	**0**	30	30	70	70	**100**
HE-12	**0**	30	30	65	65	**100**
HE-13	**0**	20	20	60	60	**100**
HE-14	**0**	30	30	70	70	**100**

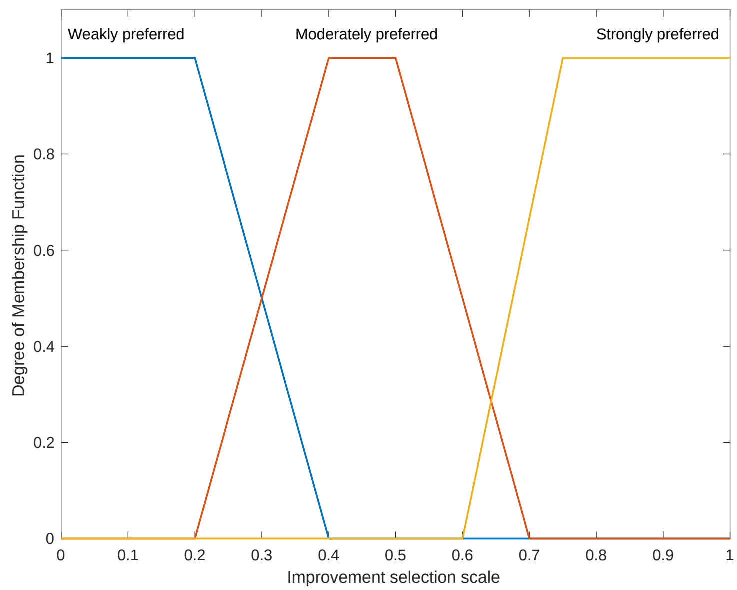


Figure 5-14: Improvement classification membership function

Table 5-50 demonstrates the results of expert knowledge acquisition; it illustrates each factor and the utilized linguistic class and the corresponding fuzzy number. Also, the linguistic class and the corresponding fuzzy number for improvement classification was found so as to be used in the integration layer in the FIS.

The result of expert knowledge acquisition illustrates the differences among the subject matter experts' perspectives. The variation in the assessment is due to the experts' different backgrounds and experience. Gathering different perspectives helps to avoid overestimation or underestimation and reduce bias.

Table 5-50: Linguistic class and the corresponding fuzzy number for the factors

Factor	Linguistic class	Corresponding Fuzzy number
Patient's satisfaction	Very Low	[0, 0, 0.05, 0.35]
	Low	[0.06, 0.2, 0.51, 0.7]
	Moderate	[0.2, 0.4, 0.7, 0.85]
	High	[0.4, 0.6, 0.85, 0.97]
	Very High	[0.6, 0.98, 1, 1]
Health and Safety	Very Low	[0, 0, 0.2, 0.7]
	Low	[0.2, 0.4, 0.75, 0.8]
	Moderate	[0.4, 0.7, 0.85, 0.9]
	High	[0.7, 0.85, 0.9, 0.98]
	Very High	[0.85, 0.99, 1, 1]
Reputational image	Very Low	[0, 0, 0.1, 0.5]
	Low	[0.1, 0.25, 0.55, 0.7]
	Moderate	[0.25, 0.5, 0.71, 0.85]
	High	[0.5, 0.7, 0.85, 0.95]
	Very High	[0.7, 0.96, 1, 1]
Sustainability	Very Low	[0, 0, 0.1, 0.6]
	Low	[0.1, 0.3, 0.6, 0.7]
	Moderate	[0.31, 0.5, 0.7, 0.85]
	High	[0.51, 0.79, 0.85, 0.94]
	Very High	[0.8, 0.95, 1, 1]
Resource and information availability	Very Low	[0, 0, 0.05, 0.49]
	Low	[0.06, 0.3, 0.5, 0.6]
	Moderate	[0.3, 0.6, 0.7, 0.85]
	High	[0.6, 0.8, 0.88, 0.94]
	Very High	[0.8, 0.95, 1, 1]
Top management commitment	Very Low	[0, 0, 0.05, 0.5]
	Low	[0.06, 0.49, 0.5, 0.74]
	Moderate	[0.5, 0.6, 0.75, 0.89]
	High	[0.6, 0.8, 0.9, 0.94]
	Very High	[0.8, 0.95, 1, 1]
Evidence based	Very Low	[0, 0, 0.05, 0.5]
	Low	[0.06, 0.44, 0.51, 0.7]
	Moderate	[0.4, 0.5, 0.8, 0.9]
	High	[0.5, 0.6, 0.9, 0.95]
	Very High	[0.6, 0.96, 1, 1]

Factor	Linguistic class	Corresponding Fuzzy number
Critical to quality	Very Low Low Moderate High Very High	[0, 0, 0.05, 0.5] [0.06, 0.4, 0.51, 0.79] [0.4, 0.6, 0.8, 0.89] [0.6, 0.8, 0.9, 0.98] [0.8, 0.99, 1, 1]
Ethical implication	Very Low Low Moderate High Very High	[0, 0, 0.1, 0.4] [0.1, 0.3, 0.4, 0.7] [0.31, 0.45, 0.7, 0.9] [0.45, 0.6, 0.9, 0.95] [0.6, 0.95, 1, 1]
Creativity and innovation	Very Low Low Moderate High Very High	[0, 0, 0.05, 0.39] [0.05, 0.2, 0.4, 0.6] [0.21, 0.5, 0.6, 0.85] [0.5, 0.7, 0.85, 0.94] [0.7, 0.95, 1, 1]
Improvement classification	Weakly preferred Moderately preferred Strongly preferred	[0, 0, 0.2, 0.4] [0.2 ,0.4, 0.5, 0.7] [0.6, 0.75, 1, 1]

5.6 Results of Fuzzy Interface System

Simulink and the Fuzzy Logic Toolbox in MATLAB was utilized to build the fuzzy system along with the data gathered from the experts. This section presents the results from the fuzzy interface system for each hospital. Only internal EFQM certified experts in the hospital participated in answering the last survey; thus the total number of experts is less than that in the first phase. A" CA-k" was used as assigned code for each participant, where CA stands for the EFQM Certified Assessor, and k stands for the participant number. Each expert rated EFQM's sub-criteria subject to the selected factors. For example, the question was, subject to Health & Safety, the expected performance of improvement projects related to (1a. Leaders develop the mission, vision, values and ethics and act as role models) was determined to be: VL, L, M, H, or

VH. Note that out of the 32 sub-criteria, only 24 were included, as the facilities believed that enablers' sub-criteria are more related to improvement since they cover what and how the organization do. Then all of the experts' ratings were aggregated to end up with crisp values to be used as inputs to the Simulink model.

The Simulink model was used to find the priority index for each alternative. The model was built based on the number of the critical evaluation factors selected in the Fuzzy Delphi method. The model inputs are the results obtained from the alternative rating from each factor perspective and the weight assigned to each factor from Fuzzy Delphi step. The assigned weights indicate the difference between factors importance from the facilities' point of view. The model consists of several Mamdani FISs built using the Fuzzy Logic Toolbox. The FISs were supplied with membership functions obtained from the experts' knowledge acquisition step.

5.6.1 Results for Hospital A

Table 5-51 to Table 5-58 below lay out the experts' ratings for each alternative with respect to the critical factors and the average fuzzy number. Five EFQM certified assessors in the facility participated in rating the 24 sub-criteria; consequently a total of 960 ratings were given for the expected performance. These ratings were aggregated using the fuzzy set in Table 4-5 and the membership function in Figure 4-10 to end up with 192 fuzzy numbers for expected performance. Then the fuzzy numbers of the expected performance were multiplied by the fuzzy value of the factor's weight to incorporate the factor importance in the ranking process, as shown in

Table *5-59*. Finally, the fuzzy number of the results was defuzzified to get 192 crisp values. Table 5-60 summarizes the results of aggregating the EFQM assessors' ratings for each alternative.

Table 5-51: EFQM sub-criteria ratings subject to the patient satisfaction factor for Hospital A

	Linguistic rating					Fuzzy numbers					
	CA-1	CA-2	CA-3	CA-4	CA-5	CA-1	CA-2	CA-3	CA-4	CA-5	Average Fuzzy Number
1a.	H	H	H	H	H	[60,75,90]	[60,75,90]	[60,75,90]	[60,75,90]	[60,75,90]	[60,75,90]
1b.	H	H	VH	M	H	[60,75,90]	[60,75,90]	[85,100,100]	[35,50,65]	[60,75,90]	[60,75,87]
1c.	H	H	VH	H	VH	[60,75,90]	[60,75,90]	[85,100,100]	[60,75,90]	[85,100,100]	[70,85,94]
1d.	H	H	VH	H	H	[60,75,90]	[60,75,90]	[85,100,100]	[60,75,90]	[60,75,90]	[65,80,92]
1e.	H	H	H	H	L	[60,75,90]	[60,75,90]	[60,75,90]	[60,75,90]	[10,25,40]	[50,65,80]
2a.	H	H	VH	H	M	[60,75,90]	[60,75,90]	[85,100,100]	[60,75,90]	[35,50,65]	[60,75,87]
2b.	H	M	M	H	H	[60,75,90]	[35,50,65]	[35,50,65]	[60,75,90]	[60,75,90]	[50,65,80]
2c.	H	M	M	VH	M	[60,75,90]	[35,50,65]	[35,50,65]	[85,100,100]	[35,50,65]	[50,65,77]
2d.	M	M	M	VH	M	[35,50,65]	[35,50,65]	[35,50,65]	[85,100,100]	[35,50,65]	[45,60,72]
3a.	H	H	H	VH	L	[60,75,90]	[60,75,90]	[60,75,90]	[85,100,100]	[10,25,40]	[55,70,82]
3b.	H	H	H	VH	M	[60,75,90]	[60,75,90]	[60,75,90]	[85,100,100]	[35,50,65]	[60,75,87]
3c.	H	H	VH	VH	L	[60,75,90]	[60,75,90]	[85,100,100]	[85,100,100]	[10,25,40]	[60,75,84]
3d.	H	H	VH	VH	M	[60,75,90]	[60,75,90]	[85,100,100]	[85,100,100]	[35,50,65]	[65,80,89]
3e.	H	M	VH	VH	VL	[60,75,90]	[35,50,65]	[85,100,100]	[85,100,100]	[0,0,15]	[53,65,74]
4a.	M	M	H	VH	H	[35,50,65]	[35,50,65]	[60,75,90]	[85,100,100]	[60,75,90]	[55,70,82]
4b.	M	M	H	VH	VL	[35,50,65]	[35,50,65]	[60,75,90]	[85,100,100]	[0,0,15]	[43,55,67]
4c.	H	H	H	VH	H	[60,75,90]	[60,75,90]	[60,75,90]	[85,100,100]	[60,75,90]	[65,80,92]
4d.	H	H	H	VH	M	[60,75,90]	[60,75,90]	[60,75,90]	[85,100,100]	[35,50,65]	[60,75,87]
4e.	M	M	H	VH	H	[35,50,65]	[35,50,65]	[60,75,90]	[85,100,100]	[60,75,90]	[55,70,82]
5a.	H	M	M	VH	VH	[60,75,90]	[35,50,65]	[35,50,65]	[85,100,100]	[85,100,100]	[60,75,84]
5b.	H	H	VH	VH	VH	[60,75,90]	[60,75,90]	[85,100,100]	[85,100,100]	[85,100,100]	[75,90,96]
5c.	H	M	VH	VH	H	[60,75,90]	[35,50,65]	[85,100,100]	[85,100,100]	[60,75,90]	[65,80,89]
5d.	H	M	VH	H	H	[60,75,90]	[35,50,65]	[85,100,100]	[60,75,90]	[60,75,90]	[60,75,87]
5e.	VH	VH	VH	H	VH	[85,100,100]	[85,100,100]	[85,100,100]	[60,75,90]	[85,100,100]	[80,95,98]

Table 5-52: EFQM sub-criteria ratings subject to the health and safety factor for Hospital A

	Linguistic rating					Fuzzy numbers					
	CA-1	CA-2	CA-3	CA-4	CA-5	CA-1	CA-2	CA-3	CA-4	CA-5	Average Fuzzy Number
1a.	M	L	VL	H	VL	[35,50,65]	[10,25,40]	[0,0,15]	[60,75,90]	[0,0,15]	[21,30,45]
1b.	M	M	M	VH	H	[35,50,65]	[35,50,65]	[35,50,65]	[85,100,100]	[60,75,90]	[50,65,77]
1c.	M	M	M	H	M	[35,50,65]	[35,50,65]	[35,50,65]	[60,75,90]	[35,50,65]	[40,55,70]
1d.	M	M	H	H	H	[35,50,65]	[35,50,65]	[60,75,90]	[60,75,90]	[60,75,90]	[50,65,80]
1e.	M	H	H	H	M	[35,50,65]	[60,75,90]	[60,75,90]	[60,75,90]	[35,50,65]	[50,65,80]
2a.	M	M	M	VH	M	[35,50,65]	[35,50,65]	[35,50,65]	[85,100,100]	[35,50,65]	[45,60,72]
2b.	M	L	L	H	H	[35,50,65]	[10,25,40]	[10,25,40]	[60,75,90]	[60,75,90]	[35,50,65]
2c.	H	L	M	VH	H	[60,75,90]	[10,25,40]	[35,50,65]	[85,100,100]	[60,75,90]	[50,65,77]
2d.	M	M	M	VH	M	[35,50,65]	[35,50,65]	[35,50,65]	[85,100,100]	[35,50,65]	[45,60,72]
3a.	M	M	H	VH	M	[35,50,65]	[35,50,65]	[60,75,90]	[85,100,100]	[35,50,65]	[50,65,77]
3b.	H	H	VH	VH	H	[60,75,90]	[60,75,90]	[85,100,100]	[85,100,100]	[60,75,90]	[70,85,94]
3c.	H	M	VH	VH	M	[60,75,90]	[35,50,65]	[85,100,100]	[85,100,100]	[35,50,65]	[60,75,84]
3d.	H	H	VH	VH	H	[60,75,90]	[60,75,90]	[85,100,100]	[85,100,100]	[60,75,90]	[70,85,94]
3e.	M	M	VH	VH	M	[35,50,65]	[35,50,65]	[85,100,100]	[85,100,100]	[35,50,65]	[55,70,79]
4a.	H	M	M	VH	M	[60,75,90]	[35,50,65]	[35,50,65]	[85,100,100]	[35,50,65]	[50,65,77]
4b.	M	M	H	VH	VH	[35,50,65]	[35,50,65]	[60,75,90]	[85,100,100]	[85,100,100]	[60,75,84]
4c.	H	H	H	VH	VH	[60,75,90]	[60,75,90]	[60,75,90]	[85,100,100]	[85,100,100]	[70,85,94]
4d.	M	H	H	VH	H	[35,50,65]	[60,75,90]	[60,75,90]	[85,100,100]	[60,75,90]	[60,75,87]
4e.	M	M	H	VH	H	[35,50,65]	[35,50,65]	[60,75,90]	[85,100,100]	[60,75,90]	[55,70,82]
5a.	H	M	M	H	VH	[60,75,90]	[35,50,65]	[35,50,65]	[60,75,90]	[85,100,100]	[55,70,82]
5b.	M	H	M	VH	H	[35,50,65]	[60,75,90]	[35,50,65]	[85,100,100]	[60,75,90]	[55,70,82]
5c.	H	H	M	M	H	[60,75,90]	[60,75,90]	[35,50,65]	[35,50,65]	[60,75,90]	[50,65,80]
5d.	M	M	M	H	M	[35,50,65]	[35,50,65]	[35,50,65]	[60,75,90]	[35,50,65]	[40,55,70]
5e.	M	M	M	H	M	[35,50,65]	[35,50,65]	[35,50,65]	[60,75,90]	[35,50,65]	[40,55,70]

Table 5-53: EFQM sub-criteria ratings subject to the reputational image factor for Hospital A

	Linguistic rating					Fuzzy numbers					
	CA-1	CA-2	CA-3	CA-4	CA-5	CA-1	CA-2	CA-3	CA-4	CA-5	Average Fuzzy Number
1a.	H	VH	H	VH	H	[60,75,90]	[85,100,100]	[60,75,90]	[85,100,100]	[60,75,90]	[70,85,94]
1b.	H	M	M	VH	H	[60,75,90]	[35,50,65]	[35,50,65]	[85,100,100]	[60,75,90]	[55,70,82]
1c.	H	VH	VH	VH	VH	[60,75,90]	[85,100,100]	[85,100,100]	[85,100,100]	[85,100,100]	[80,95,98]
1d.	M	VH	VH	VH	VH	[35,50,65]	[85,100,100]	[85,100,100]	[85,100,100]	[85,100,100]	[75,90,93]
1e.	M	H	H	VH	M	[35,50,65]	[60,75,90]	[60,75,90]	[85,100,100]	[35,50,65]	[55,70,82]
2a.	H	H	H	VH	H	[60,75,90]	[60,75,90]	[60,75,90]	[85,100,100]	[60,75,90]	[65,80,92]
2b.	M	M	M	M	L	[35,50,65]	[35,50,65]	[35,50,65]	[35,50,65]	[10,25,40]	[30,45,60]
2c.	H	L	L	VH	M	[60,75,90]	[10,25,40]	[10,25,40]	[85,100,100]	[35,50,65]	[40,55,67]
2d.	M	L	L	VH	M	[35,50,65]	[10,25,40]	[10,25,40]	[85,100,100]	[35,50,65]	[35,50,62]
3a.	M	H	H	VH	L	[35,50,65]	[60,75,90]	[60,75,90]	[85,100,100]	[10,25,40]	[50,65,77]
3b.	H	VH	H	VH	L	[60,75,90]	[85,100,100]	[60,75,90]	[85,100,100]	[10,25,40]	[60,75,84]
3c.	M	M	H	VH	L	[35,50,65]	[35,50,65]	[60,75,90]	[85,100,100]	[10,25,40]	[45,60,72]
3d.	H	H	H	VH	M	[60,75,90]	[60,75,90]	[60,75,90]	[85,100,100]	[35,50,65]	[60,75,87]
3e.	H	VH	H	VH	L	[60,75,90]	[85,100,100]	[60,75,90]	[85,100,100]	[10,25,40]	[60,75,84]
4a.	M	M	H	VH	H	[35,50,65]	[35,50,65]	[60,75,90]	[85,100,100]	[60,75,90]	[55,70,82]
4b.	VH	M	H	VH	VL	[85,100,100]	[35,50,65]	[60,75,90]	[85,100,100]	[0,0,15]	[53,65,74]
4c.	H	H	H	VH	H	[60,75,90]	[60,75,90]	[60,75,90]	[85,100,100]	[60,75,90]	[65,80,92]
4d.	M	H	H	VH	L	[35,50,65]	[60,75,90]	[60,75,90]	[85,100,100]	[10,25,40]	[50,65,77]
4e.	M	M	H	VH	M	[35,50,65]	[35,50,65]	[60,75,90]	[85,100,100]	[35,50,65]	[50,65,77]
5a.	VH	M	VH	VH	H	[85,100,100]	[35,50,65]	[85,100,100]	[85,100,100]	[60,75,90]	[70,85,91]
5b.	M	H	VH	VH	H	[35,50,65]	[60,75,90]	[85,100,100]	[85,100,100]	[60,75,90]	[65,80,89]
5c.	H	H	VH	VH	H	[60,75,90]	[60,75,90]	[85,100,100]	[85,100,100]	[60,75,90]	[70,85,94]
5d.	M	M	VH	VH	H	[35,50,65]	[35,50,65]	[85,100,100]	[85,100,100]	[60,75,90]	[60,75,84]
5e.	H	VH	VH	VH	VH	[60,75,90]	[85,100,100]	[85,100,100]	[85,100,100]	[85,100,100]	[80,95,98]

Table 5-54: EFQM sub-criteria ratings subject to the sustainability factor for Hospital A

	Linguistic rating					Fuzzy numbers					
	CA-1	CA-2	CA-3	CA-4	CA-5	CA-1	CA-2	CA-3	CA-4	CA-5	Average Fuzzy Number
1a.	H	H	H	VH	L	[60,75,90]	[60,75,90]	[60,75,90]	[85,100,100]	[10,25,40]	[55,70,82]
1b.	H	H	H	M	H	[60,75,90]	[60,75,90]	[60,75,90]	[35,50,65]	[60,75,90]	[55,70,85]
1c.	M	H	VH	H	M	[35,50,65]	[60,75,90]	[85,100,100]	[60,75,90]	[35,50,65]	[55,70,82]
1d.	M	H	VH	H	H	[35,50,65]	[60,75,90]	[85,100,100]	[60,75,90]	[60,75,90]	[60,75,87]
1e.	M	H	H	H	M	[35,50,65]	[60,75,90]	[60,75,90]	[60,75,90]	[35,50,65]	[50,65,80]
2a.	H	H	H	H	H	[60,75,90]	[60,75,90]	[60,75,90]	[60,75,90]	[60,75,90]	[60,75,90]
2b.	H	M	VH	H	M	[60,75,90]	[35,50,65]	[85,100,100]	[60,75,90]	[35,50,65]	[55,70,82]
2c.	M	M	VH	VH	VH	[35,50,65]	[35,50,65]	[85,100,100]	[85,100,100]	[85,100,100]	[65,80,86]
2d.	H	M	VH	VH	VH	[60,75,90]	[35,50,65]	[85,100,100]	[85,100,100]	[85,100,100]	[70,85,91]
3a.	M	M	H	VH	H	[35,50,65]	[35,50,65]	[60,75,90]	[85,100,100]	[60,75,90]	[55,70,82]
3b.	H	M	H	VH	M	[60,75,90]	[35,50,65]	[60,75,90]	[85,100,100]	[35,50,65]	[55,70,82]
3c.	M	M	H	VH	M	[35,50,65]	[35,50,65]	[60,75,90]	[85,100,100]	[35,50,65]	[50,65,77]
3d.	M	M	H	VH	H	[35,50,65]	[35,50,65]	[60,75,90]	[85,100,100]	[60,75,90]	[55,70,82]
3e.	H	M	H	M	M	[60,75,90]	[35,50,65]	[60,75,90]	[35,50,65]	[35,50,65]	[45,60,75]
4a.	M	M	VH	VH	VH	[35,50,65]	[35,50,65]	[85,100,100]	[85,100,100]	[85,100,100]	[65,80,86]
4b.	H	M	H	VH	VH	[60,75,90]	[35,50,65]	[60,75,90]	[85,100,100]	[85,100,100]	[65,80,89]
4c.	H	H	H	VH	H	[60,75,90]	[60,75,90]	[60,75,90]	[85,100,100]	[60,75,90]	[65,80,92]
4d.	H	H	H	VH	H	[60,75,90]	[60,75,90]	[60,75,90]	[85,100,100]	[60,75,90]	[65,80,92]
4e.	H	M	H	VH	H	[60,75,90]	[35,50,65]	[60,75,90]	[85,100,100]	[60,75,90]	[60,75,87]
5a.	H	M	H	H	H	[60,75,90]	[35,50,65]	[60,75,90]	[60,75,90]	[60,75,90]	[55,70,85]
5b.	M	H	H	VH	H	[35,50,65]	[60,75,90]	[60,75,90]	[85,100,100]	[60,75,90]	[60,75,87]
5c.	H	M	H	H	H	[60,75,90]	[35,50,65]	[60,75,90]	[60,75,90]	[60,75,90]	[55,70,85]
5d.	M	M	H	H	M	[35,50,65]	[35,50,65]	[60,75,90]	[60,75,90]	[35,50,65]	[45,60,75]
5e.	M	H	H	H	M	[35,50,65]	[60,75,90]	[60,75,90]	[60,75,90]	[35,50,65]	[50,65,80]

Table 5-55: EFQM sub-criteria ratings subject to the evidence-based factor.

	Linguistic rating					Fuzzy numbers					
	CA-1	CA-2	CA-3	CA-4	CA-5	CA-1	CA-2	CA-3	CA-4	CA-5	Average Fuzzy Number
1a.	H	L	VL	H	M	[60,75,90]	[10,25,40]	[0,0,15]	[60,75,90]	[35,50,65]	[33,45,60]
1b.	H	M	M	M	H	[60,75,90]	[35,50,65]	[35,50,65]	[35,50,65]	[60,75,90]	[45,60,75]
1c.	M	L	L	H	M	[35,50,65]	[10,25,40]	[10,25,40]	[60,75,90]	[35,50,65]	[30,45,60]
1d.	M	M	M	H	H	[35,50,65]	[35,50,65]	[35,50,65]	[60,75,90]	[60,75,90]	[45,60,75]
1e.	M	M	H	H	M	[35,50,65]	[35,50,65]	[60,75,90]	[60,75,90]	[35,50,65]	[45,60,75]
2a.	M	M	H	VH	M	[35,50,65]	[35,50,65]	[60,75,90]	[85,100,100]	[35,50,65]	[50,65,77]
2b.	H	L	L	H	H	[60,75,90]	[10,25,40]	[10,25,40]	[60,75,90]	[60,75,90]	[40,55,70]
2c.	H	M	L	VH	M	[60,75,90]	[35,50,65]	[10,25,40]	[85,100,100]	[35,50,65]	[45,60,72]
2d.	M	M	L	VH	M	[35,50,65]	[35,50,65]	[10,25,40]	[85,100,100]	[35,50,65]	[40,55,67]
3a.	M	M	H	VH	L	[35,50,65]	[35,50,65]	[60,75,90]	[85,100,100]	[10,25,40]	[45,60,72]
3b.	M	M	VH	VH	L	[35,50,65]	[35,50,65]	[85,100,100]	[85,100,100]	[10,25,40]	[50,65,74]
3c.	M	M	H	VH	L	[35,50,65]	[35,50,65]	[60,75,90]	[85,100,100]	[10,25,40]	[45,60,72]
3d.	M	M	H	VH	M	[35,50,65]	[35,50,65]	[60,75,90]	[85,100,100]	[35,50,65]	[50,65,77]
3e.	M	M	H	M	M	[35,50,65]	[35,50,65]	[60,75,90]	[35,50,65]	[35,50,65]	[40,55,70]
4a.	M	M	M	VH	VH	[35,50,65]	[35,50,65]	[35,50,65]	[85,100,100]	[85,100,100]	[55,70,79]
4b.	M	M	H	VH	VH	[35,50,65]	[35,50,65]	[60,75,90]	[85,100,100]	[85,100,100]	[60,75,84]
4c.	H	M	H	M	H	[60,75,90]	[35,50,65]	[60,75,90]	[35,50,65]	[60,75,90]	[50,65,80]
4d.	M	H	H	VH	H	[35,50,65]	[60,75,90]	[60,75,90]	[85,100,100]	[60,75,90]	[60,75,87]
4e.	M	M	H	VH	H	[35,50,65]	[35,50,65]	[60,75,90]	[85,100,100]	[60,75,90]	[55,70,82]
5a.	H	M	M	M	H	[60,75,90]	[35,50,65]	[35,50,65]	[35,50,65]	[60,75,90]	[45,60,75]
5b.	M	M	M	VH	H	[35,50,65]	[35,50,65]	[35,50,65]	[85,100,100]	[60,75,90]	[50,65,77]
5c.	M	M	M	M	H	[35,50,65]	[35,50,65]	[35,50,65]	[35,50,65]	[60,75,90]	[40,55,70]
5d.	M	M	M	H	H	[35,50,65]	[35,50,65]	[35,50,65]	[60,75,90]	[60,75,90]	[45,60,75]
5e.	M	M	M	H	H	[35,50,65]	[35,50,65]	[35,50,65]	[60,75,90]	[60,75,90]	[45,60,75]

Table 5-56: EFQM sub-criteria ratings subject to the critical to quality factor for Hospital A

	Linguistic rating					Fuzzy numbers					
	CA-1	CA-2	CA-3	CA-4	CA-5	CA-1	CA-2	CA-3	CA-4	CA-5	Average Fuzzy Number
1a.	H	M	M	H	M	[60,75,90]	[35,50,65]	[35,50,65]	[60,75,90]	[35,50,65]	[45,60,75]
1b.	H	M	M	VH	H	[60,75,90]	[35,50,65]	[35,50,65]	[85,100,100]	[60,75,90]	[55,70,82]
1c.	M	H	H	H	M	[35,50,65]	[60,75,90]	[60,75,90]	[60,75,90]	[35,50,65]	[50,65,80]
1d.	M	H	H	H	H	[35,50,65]	[60,75,90]	[60,75,90]	[60,75,90]	[60,75,90]	[55,70,85]
1e.	M	H	H	H	M	[35,50,65]	[60,75,90]	[60,75,90]	[60,75,90]	[35,50,65]	[50,65,80]
2a.	M	H	H	H	M	[35,50,65]	[60,75,90]	[60,75,90]	[60,75,90]	[35,50,65]	[50,65,80]
2b.	H	M	M	H	M	[60,75,90]	[35,50,65]	[35,50,65]	[60,75,90]	[35,50,65]	[45,60,75]
2c.	M	M	M	VH	H	[35,50,65]	[35,50,65]	[35,50,65]	[85,100,100]	[60,75,90]	[50,65,77]
2d.	H	M	M	VH	L	[60,75,90]	[35,50,65]	[35,50,65]	[85,100,100]	[10,25,40]	[45,60,72]
3a.	M	H	H	VH	M	[35,50,65]	[60,75,90]	[60,75,90]	[85,100,100]	[35,50,65]	[55,70,82]
3b.	H	M	H	VH	M	[60,75,90]	[35,50,65]	[60,75,90]	[85,100,100]	[35,50,65]	[55,70,82]
3c.	H	M	VH	VH	M	[60,75,90]	[35,50,65]	[85,100,100]	[85,100,100]	[35,50,65]	[60,75,84]
3d.	H	M	VH	VH	H	[60,75,90]	[35,50,65]	[85,100,100]	[85,100,100]	[60,75,90]	[65,80,89]
3e.	H	H	VH	VH	M	[60,75,90]	[60,75,90]	[85,100,100]	[85,100,100]	[35,50,65]	[65,80,89]
4a.	H	M	H	VH	H	[60,75,90]	[35,50,65]	[60,75,90]	[85,100,100]	[60,75,90]	[60,75,87]
4b.	H	M	H	VH	VH	[60,75,90]	[35,50,65]	[60,75,90]	[85,100,100]	[85,100,100]	[65,80,89]
4c.	M	H	H	VH	H	[35,50,65]	[60,75,90]	[60,75,90]	[85,100,100]	[60,75,90]	[60,75,87]
4d.	H	H	H	VH	VH	[60,75,90]	[60,75,90]	[60,75,90]	[85,100,100]	[85,100,100]	[70,85,94]
4e.	M	M	H	VH	H	[35,50,65]	[35,50,65]	[60,75,90]	[85,100,100]	[60,75,90]	[55,70,82]
5a.	H	M	M	H	VH	[60,75,90]	[35,50,65]	[35,50,65]	[60,75,90]	[85,100,100]	[55,70,82]
5b.	H	H	M	VH	H	[60,75,90]	[60,75,90]	[35,50,65]	[85,100,100]	[60,75,90]	[60,75,87]
5c.	M	M	M	M	H	[35,50,65]	[35,50,65]	[35,50,65]	[35,50,65]	[60,75,90]	[40,55,70]
5d.	H	M	M	H	H	[60,75,90]	[35,50,65]	[35,50,65]	[60,75,90]	[60,75,90]	[50,65,80]
5e.	M	H	M	H	H	[35,50,65]	[60,75,90]	[35,50,65]	[60,75,90]	[60,75,90]	[50,65,80]

Table 5-57: EFQM sub-criteria ratings subject to the top management commitment factor for Hospital A

	Linguistic rating					Fuzzy numbers					
	CA-1	CA-2	CA-3	CA-4	CA-5	CA-1	CA-2	CA-3	CA-4	CA-5	Average Fuzzy Number
1a.	VH	VH	VH	VH	H	[85,100,100]	[85,100,100]	[85,100,100]	[85,100,100]	[60,75,90]	[80,95,98]
1b.	H	VH	VH	H	VH	[60,75,90]	[85,100,100]	[85,100,100]	[60,75,90]	[85,100,100]	[75,90,96]
1c.	H	VH	VH	H	VH	[60,75,90]	[85,100,100]	[85,100,100]	[60,75,90]	[85,100,100]	[75,90,96]
1d.	H	VH	VH	H	H	[60,75,90]	[85,100,100]	[85,100,100]	[60,75,90]	[60,75,90]	[70,85,94]
1e.	H	H	H	H	H	[60,75,90]	[60,75,90]	[60,75,90]	[60,75,90]	[60,75,90]	[60,75,90]
2a.	H	H	H	H	H	[60,75,90]	[60,75,90]	[60,75,90]	[60,75,90]	[60,75,90]	[60,75,90]
2b.	H	H	H	H	VH	[60,75,90]	[60,75,90]	[60,75,90]	[60,75,90]	[85,100,100]	[65,80,92]
2c.	H	H	H	VH	VH	[60,75,90]	[60,75,90]	[60,75,90]	[85,100,100]	[85,100,100]	[70,85,94]
2d.	H	H	H	VH	VH	[60,75,90]	[60,75,90]	[60,75,90]	[85,100,100]	[85,100,100]	[70,85,94]
3a.	H	H	H	VH	M	[60,75,90]	[60,75,90]	[60,75,90]	[85,100,100]	[35,50,65]	[60,75,87]
3b.	VH	H	H	VH	M	[85,100,100]	[60,75,90]	[60,75,90]	[85,100,100]	[35,50,65]	[65,80,89]
3c.	H	H	H	VH	L	[60,75,90]	[60,75,90]	[60,75,90]	[85,100,100]	[10,25,40]	[55,70,82]
3d.	H	M	H	VH	H	[60,75,90]	[35,50,65]	[60,75,90]	[85,100,100]	[60,75,90]	[60,75,87]
3e.	H	M	H	VH	H	[60,75,90]	[35,50,65]	[60,75,90]	[85,100,100]	[60,75,90]	[60,75,87]
4a.	H	M	H	M	VH	[60,75,90]	[35,50,65]	[60,75,90]	[35,50,65]	[85,100,100]	[55,70,82]
4b.	VH	M	H	M	VH	[85,100,100]	[35,50,65]	[60,75,90]	[35,50,65]	[85,100,100]	[60,75,84]
4c.	H	H	H	M	H	[60,75,90]	[60,75,90]	[60,75,90]	[35,50,65]	[60,75,90]	[55,70,85]
4d.	H	H	H	VH	H	[60,75,90]	[60,75,90]	[60,75,90]	[85,100,100]	[60,75,90]	[65,80,92]
4e.	H	M	H	VH	H	[60,75,90]	[35,50,65]	[60,75,90]	[85,100,100]	[60,75,90]	[60,75,87]
5a.	H	H	H	H	H	[60,75,90]	[60,75,90]	[60,75,90]	[60,75,90]	[60,75,90]	[60,75,90]
5b.	H	H	H	VH	H	[60,75,90]	[60,75,90]	[60,75,90]	[85,100,100]	[60,75,90]	[65,80,92]
5c.	H	M	H	M	H	[60,75,90]	[35,50,65]	[60,75,90]	[35,50,65]	[60,75,90]	[50,65,80]
5d.	H	H	H	H	M	[60,75,90]	[60,75,90]	[60,75,90]	[60,75,90]	[35,50,65]	[55,70,85]
5e.	H	H	H	H	M	[60,75,90]	[60,75,90]	[60,75,90]	[60,75,90]	[35,50,65]	[55,70,85]

Table 5-58: EFQM sub-criteria rating subject to ethical implications factor for Hospital A

	Linguistic rating					Fuzzy number					
	CA-1	CA-2	CA-3	CA-4	CA-5	CA-1	CA-2	CA-3	CA-4	CA-5	Average Fuzzy Number
1a.	H	VH	VH	VH	VH	[60,75,90]	[85,100,100]	[85,100,100]	[85,100,100]	[85,100,100]	[80,95,98]
1b.	H	H	M	H	M	[60,75,90]	[60,75,90]	[35,50,65]	[60,75,90]	[35,50,65]	[50,65,80]
1c.	H	H	H	H	H	[60,75,90]	[60,75,90]	[60,75,90]	[60,75,90]	[60,75,90]	[60,75,90]
1d.	H	H	M	H	L	[60,75,90]	[60,75,90]	[35,50,65]	[60,75,90]	[10,25,40]	[45,60,75]
1e.	H	H	H	H	L	[60,75,90]	[60,75,90]	[60,75,90]	[60,75,90]	[10,25,40]	[50,65,80]
2a.	H	H	H	H	L	[60,75,90]	[60,75,90]	[60,75,90]	[60,75,90]	[10,25,40]	[50,65,80]
2b.	H	M	M	H	M	[60,75,90]	[35,50,65]	[35,50,65]	[60,75,90]	[35,50,65]	[45,60,75]
2c.	H	M	M	VH	M	[60,75,90]	[35,50,65]	[35,50,65]	[85,100,100]	[35,50,65]	[50,65,77]
2d.	H	M	M	VH	M	[60,75,90]	[35,50,65]	[35,50,65]	[85,100,100]	[35,50,65]	[50,65,77]
3a.	M	H	H	VH	L	[35,50,65]	[60,75,90]	[60,75,90]	[85,100,100]	[10,25,40]	[50,65,77]
3b.	M	VH	H	VH	L	[35,50,65]	[85,100,100]	[60,75,90]	[85,100,100]	[10,25,40]	[55,70,79]
3c.	H	M	VH	VH	L	[60,75,90]	[35,50,65]	[85,100,100]	[85,100,100]	[10,25,40]	[55,70,79]
3d.	H	M	VH	VH	M	[60,75,90]	[35,50,65]	[85,100,100]	[85,100,100]	[35,50,65]	[60,75,84]
3e.	M	H	VH	VH	M	[35,50,65]	[60,75,90]	[85,100,100]	[85,100,100]	[35,50,65]	[60,75,84]
4a.	H	M	H	VH	VH	[60,75,90]	[35,50,65]	[60,75,90]	[85,100,100]	[85,100,100]	[65,80,89]
4b.	H	M	H	M	M	[60,75,90]	[35,50,65]	[60,75,90]	[35,50,65]	[35,50,65]	[45,60,75]
4c.	M	M	H	M	L	[35,50,65]	[35,50,65]	[60,75,90]	[35,50,65]	[10,25,40]	[35,50,65]
4d.	M	M	H	VH	L	[35,50,65]	[35,50,65]	[60,75,90]	[85,100,100]	[10,25,40]	[45,60,72]
4e.	H	M	H	VH	L	[60,75,90]	[35,50,65]	[60,75,90]	[85,100,100]	[10,25,40]	[50,65,77]
5a.	H	M	M	H	H	[60,75,90]	[35,50,65]	[35,50,65]	[60,75,90]	[60,75,90]	[50,65,80]
5b.	M	H	M	M	M	[35,50,65]	[60,75,90]	[35,50,65]	[35,50,65]	[35,50,65]	[40,55,70]
5c.	H	M	M	M	L	[60,75,90]	[35,50,65]	[35,50,65]	[35,50,65]	[10,25,40]	[35,50,65]
5d.	M	M	M	H	M	[35,50,65]	[35,50,65]	[35,50,65]	[60,75,90]	[35,50,65]	[40,55,70]
5e.	H	H	M	H	M	[60,75,90]	[60,75,90]	[35,50,65]	[60,75,90]	[35,50,65]	[50,65,80]

Table 5-59: Fuzzy numbers for improvement's expected performance for each factor for Hospital A

	Patient satisfaction	Health and safety	Reputational image	Sustainability	Evidence based	Critical to Quality	Top management commitment	Ethical implications
1a.	[29,54.7,81.8]	[10.8,22.8,41.3]	[32.1,60,85.8]	[24.8,48.8,73.7]	[15.1,31.7,53.7]	[20.3,42,67.3]	[38.2,68.6,88]	[36.8,66.7,87.4]
1b.	[29,54.7,79.1]	[25.6,49.4,70.7]	[25.2,49.4,74.8]	[24.8,48.8,76.4]	[20.6,42.3,67.2]	[24.8,49,73.6]	[35.8,65,86.2]	[23,45.6,71.4]
1c.	[33.8,62,85.4]	[20.5,41.8,64.3]	[36.7,67.1,89.4]	[24.8,48.8,73.7]	[13.7,31.7,53.7]	[22.6,45.5,71.8]	[35.8,65,86.2]	[27.6,52.6,80.3]
1d.	[31.4,58.4,83.6]	[25.6,49.4,73.5]	[34.4,63.5,84.9]	[27.1,52.3,78.2]	[20.6,42.3,67.2]	[24.8,49,76.3]	[33.4,61.4,84.5]	[20.7,42.1,66.9]
1e.	[24.1,47.4,72.7]	[25.6,49.4,73.5]	[25.2,49.4,74.8]	[22.6,45.3,71.9]	[20.6,42.3,67.2]	[22.6,45.5,71.8]	[28.7,54.2,80.9]	[23,45.6,71.4]
2a.	[29,54.7,79.1]	[23.1,45.6,66.1]	[29.8,56.5,83.9]	[27.1,52.3,80.9]	[22.9,45.8,69]	[22.6,45.5,71.8]	[28.7,54.2,80.9]	[23,45.6,71.4]
2b.	[24.1,47.4,72.7]	[18,38,59.7]	[13.8,31.8,54.7]	[24.8,48.8,73.7]	[18.3,38.8,62.7]	[20.3,42,67.3]	[31,57.8,82.7]	[20.7,42.1,66.9]
2c.	[24.1,47.4,70]	[25.6,49.4,70.7]	[18.3,38.8,61.1]	[29.3,55.7,77.3]	[20.6,42.3,64.5]	[22.6,45.5,69.1]	[33.4,61.4,84.5]	[23,45.6,68.7]
2d.	[21.7,43.8,65.4]	[23.1,45.6,66.1]	[16,35.3,56.6]	[31.6,59.2,81.8]	[18.3,38.8,60]	[20.3,42,64.7]	[33.4,61.4,84.5]	[23,45.6,68.7]
3a.	[26.6,51.1,74.5]	[25.6,49.4,70.7]	[22.9,45.9,70.3]	[24.8,48.8,73.7]	[20.6,42.3,64.5]	[24.8,49,73.6]	[28.7,54.2,78.2]	[23,45.6,68.7]
3b.	[29,54.7,79.1]	[35.9,64.6,86.3]	[27.5,52.9,76.6]	[24.8,48.8,73.7]	[22.9,45.8,66.3]	[24.8,49,73.6]	[31,57.8,80]	[25.3,49.1,70.5]
3c.	[29,54.7,76.4]	[30.8,57,77.1]	[20.6,42.3,65.7]	[22.6,45.3,69.2]	[20.6,42.3,64.5]	[27.1,52.5,75.4]	[26.3,50.6,73.7]	[25.3,49.1,70.5]
3d.	[31.4,58.4,80.9]	[35.9,64.6,86.3]	[27.5,52.9,79.4]	[24.8,48.8,73.7]	[22.9,45.8,69]	[29.4,56,79.9]	[28.7,54.2,78.2]	[27.6,52.6,74.9]
3e.	[25.6,47.4,67.3]	[28.2,53.2,72.5]	[27.5,52.9,76.6]	[20.3,41.8,67.4]	[18.3,38.8,62.7]	[29.4,56,79.9]	[28.7,54.2,78.2]	[27.6,52.6,74.9]
4a.	[26.6,51.1,74.5]	[25.6,49.4,70.7]	[25.2,49.4,74.8]	[29.3,55.7,77.3]	[25.2,49.3,70.7]	[27.1,52.5,78.1]	[26.3,50.6,73.7]	[29.9,56.1,79.4]
4b.	[20.8,40.1,60.9]	[30.8,57,77.1]	[24.3,45.9,67.5]	[29.3,55.7,80]	[27.5,52.8,75.2]	[29.4,56,79.9]	[28.7,54.2,75.5]	[20.7,42.1,66.9]
4c.	[31.4,58.4,83.6]	[35.9,64.6,86.3]	[29.8,56.5,83.9]	[29.3,55.7,82.7]	[22.9,45.8,71.6]	[27.1,52.5,78.1]	[26.3,50.6,76.4]	[16.1,35.1,58]
4d.	[29,54.7,79.1]	[30.8,57,79.9]	[22.9,45.9,70.3]	[29.3,55.7,82.7]	[27.5,52.8,77.9]	[31.6,59.5,84.4]	[31,57.8,82.7]	[20.7,42.1,64.2]
4e.	[26.6,51.1,74.5]	[28.2,53.2,75.3]	[22.9,45.9,70.3]	[27.1,52.3,78.2]	[25.2,49.3,73.4]	[24.8,49,73.6]	[28.7,54.2,78.2]	[23,45.6,68.7]
5a.	[29,54.7,76.4]	[28.2,53.2,75.3]	[32.1,60,83]	[24.8,48.8,76.4]	[20.6,42.3,67.2]	[24.8,49,73.6]	[28.7,54.2,80.9]	[23,45.6,71.4]
5b.	[36.2,65.7,87.3]	[28.2,53.2,75.3]	[29.8,56.5,81.2]	[27.1,52.3,78.2]	[22.9,45.8,69]	[27.1,52.5,78.1]	[31,57.8,82.7]	[18.4,38.6,62.4]
5c.	[31.4,58.4,80.9]	[25.6,49.4,73.5]	[32.1,60,85.8]	[24.8,48.8,76.4]	[18.3,38.8,62.7]	[18.1,38.5,62.9]	[23.9,47,71.9]	[16.1,35.1,58]
5d.	[29,54.7,79.1]	[20.5,41.8,64.3]	[27.5,52.9,76.6]	[20.3,41.8,67.4]	[20.6,42.3,67.2]	[22.6,45.5,71.8]	[26.3,50.6,76.4]	[18.4,38.6,62.4]
5e	[38.6,69.3,89.1]	[20.5,41.8,64.3]	[36.7,67.1,89.4]	[22.6,45.3,71.9]	[20.6,42.3,67.2]	[22.6,45.5,71.8]	[26.3,50.6,76.4]	[23,45.6,71.4]

Table 5-60: Crisp values for improvements' expected performance for Hospital A

	Patient satisfaction	Health and safety	Reputational image	Sustainability	Evidence based	Critical to Quality	Top management commitment	Ethical implications
1a.	55.17	24.96	59.28	49.09	33.50	43.20	64.96	63.62
1b.	54.26	48.58	49.81	49.98	43.37	49.13	62.36	46.66
1c.	60.42	42.20	64.38	49.09	33.03	46.63	62.36	53.50
1d.	57.80	49.50	60.92	52.49	43.37	50.03	59.76	43.24
1e.	48.10	49.50	49.81	46.57	43.37	46.63	54.57	46.66
2a.	54.26	44.93	56.74	53.39	45.90	46.63	54.57	46.66
2b.	48.10	38.54	33.42	49.09	39.93	43.20	57.16	43.24
2c.	47.19	48.58	39.43	54.11	42.47	45.73	59.76	45.76
2d.	43.65	44.93	35.97	57.52	39.03	42.33	59.76	45.76
3a.	50.72	48.58	46.35	49.09	42.47	49.13	53.67	45.76
3b.	54.26	62.27	52.36	49.09	45.00	49.13	56.27	48.30
3c.	53.35	54.97	42.89	45.67	42.47	51.67	50.17	48.30
3d.	56.89	62.27	53.28	49.09	45.90	55.10	53.67	51.72
3e.	46.76	51.31	52.36	43.16	39.93	55.10	53.67	51.72
4a.	50.72	48.58	49.81	54.11	48.40	52.57	50.17	55.14
4b.	40.60	54.97	45.90	55.01	51.83	55.10	52.77	43.24
4c.	57.80	62.27	56.74	55.90	46.77	52.57	51.06	36.39
4d.	54.26	55.88	46.35	55.90	52.73	58.50	57.16	42.34
4e.	50.72	52.23	46.35	52.49	49.30	49.13	53.67	45.76
5a.	53.35	52.23	58.37	49.98	43.37	49.13	54.57	46.66
5b.	63.05	52.23	55.82	52.49	45.90	52.57	57.16	39.81
5c.	56.89	49.50	59.28	49.98	39.93	39.83	47.57	36.39
5d.	54.26	42.20	52.36	43.16	43.37	46.63	51.06	39.81
5e	65.68	42.20	64.38	46.57	43.37	46.63	51.06	46.66

The multiplication of the factors' weights by the improvements' expected performance reduced the improvements' expected performance range. Thus, the fuzzy numbers obtained from the multiplication process were defuzzified and normalized as shown in Table 5-61. Those values were used as inputs for the FIS system.

Table 5-61: Improvements' expected performance after normalization for Hospital A

	Patient satisfaction	Health and safety	Reputational image	sustainability	Evidence-based	Critical to Quality	Top management commitment	Ethical implication
1a.	0.58	0.00	0.84	0.41	0.02	0.18	1.00	1.00
1b.	0.54	0.63	0.53	0.48	0.52	0.50	0.85	0.38
1c.	0.79	0.46	1.00	0.41	0.00	0.36	0.85	0.63
1d.	0.69	0.66	0.89	0.65	0.52	0.55	0.70	0.25
1e.	0.30	0.66	0.53	0.24	0.52	0.36	0.40	0.38
2a.	0.54	0.54	0.75	0.71	0.65	0.36	0.40	0.38
2b.	0.30	0.36	0.00	0.41	0.35	0.18	0.55	0.25
2c.	0.26	0.63	0.19	0.76	0.48	0.32	0.70	0.34
2d.	0.12	0.54	0.08	1.00	0.30	0.13	0.70	0.34
3a.	0.40	0.63	0.42	0.41	0.48	0.50	0.35	0.34
3b.	0.54	1.00	0.61	0.41	0.61	0.50	0.50	0.44
3c.	0.51	0.80	0.31	0.17	0.48	0.63	0.15	0.44
3d.	0.65	1.00	0.64	0.41	0.65	0.82	0.35	0.56
3e.	0.25	0.71	0.61	0.00	0.35	0.82	0.35	0.56
4a.	0.40	0.63	0.53	0.76	0.78	0.68	0.15	0.69
4b.	0.00	0.80	0.40	0.83	0.95	0.82	0.30	0.25
4c.	0.69	1.00	0.75	0.89	0.70	0.68	0.20	0.00
4d.	0.54	0.83	0.42	0.89	1.00	1.00	0.55	0.22
4e.	0.40	0.73	0.42	0.65	0.83	0.50	0.35	0.34
5a.	0.51	0.73	0.81	0.48	0.52	0.50	0.40	0.38
5b.	0.90	0.73	0.72	0.65	0.65	0.68	0.55	0.13
5c.	0.65	0.66	0.84	0.48	0.35	0.00	0.00	0.00
5d.	0.54	0.46	0.61	0.00	0.52	0.36	0.20	0.13
5e	1.00	0.46	1.00	0.24	0.52	0.36	0.20	0.38

The values obtained were the inputs for the ranking model in Figure 5-15. The model consists of 8 inputs, seven FISs, and one output. The first five FISs attempted to calculate an index for each dimensions whereas the last two FISs combined those indexes and determined the priority index used to rank the alternatives. The figure illustrates an example of calculating the priority index for (1.a) sub-criteria. Notice that the complement for ethical implications was found through subtracting the value from 1, as seen in the figure.

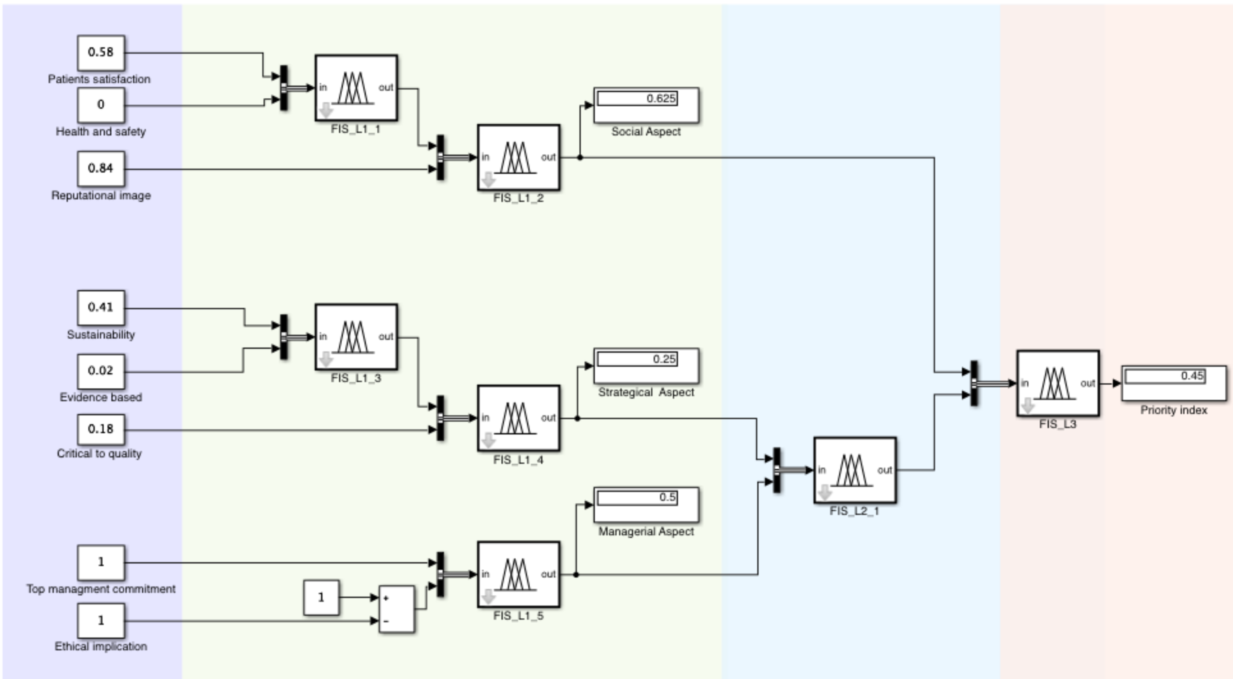


Figure 5-15: Implementation of the ranking model using Simulink for Hospital A

The Fuzzy Logic Toolbox in MATLAB was used to build each FIS in the model. This was accomplished through including the developed membership functions from the expert's knowledge acquisition and the identified rules in chapter 4. Note that the intermediate indexes and the priority rankings were found through the simulation. However, A 3-D surface plot for each subsystem was generated to allow a better understanding of the function of each FIS in addition to visualizing the relation between the inputs and the output. "FIS_Ln_k" notation was used to identify the FIS system; where Ln stands for the layer, and k the number of the subsystem.

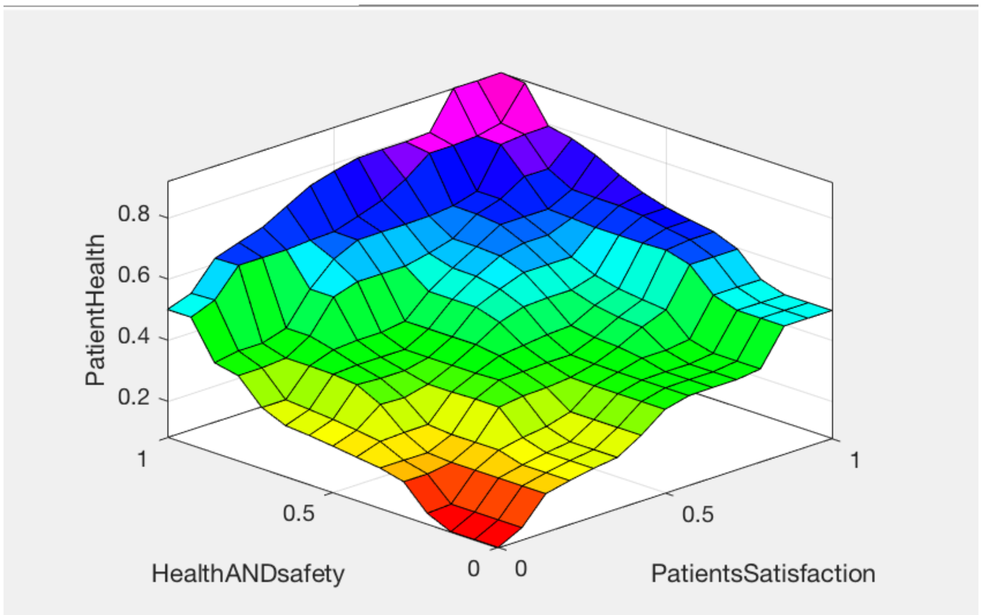


Figure 5-16: Surface of the FIS-L1-1

Figure 5-16 demonstrates the surface of the first subsystem in the dimensions layer. The inputs were patient satisfaction and health and safety, while the output was an intermediate value that combined both values. The input values were between 0 and 1 and the surface output between 0.08 to 0.92 due to the defuzzification using the centroid method. The output increases if any input increases while the other input is held constant. The output increases with the increment of any inputs' in the lower value, nevertheless output's higher values require larger alternation of both inputs.

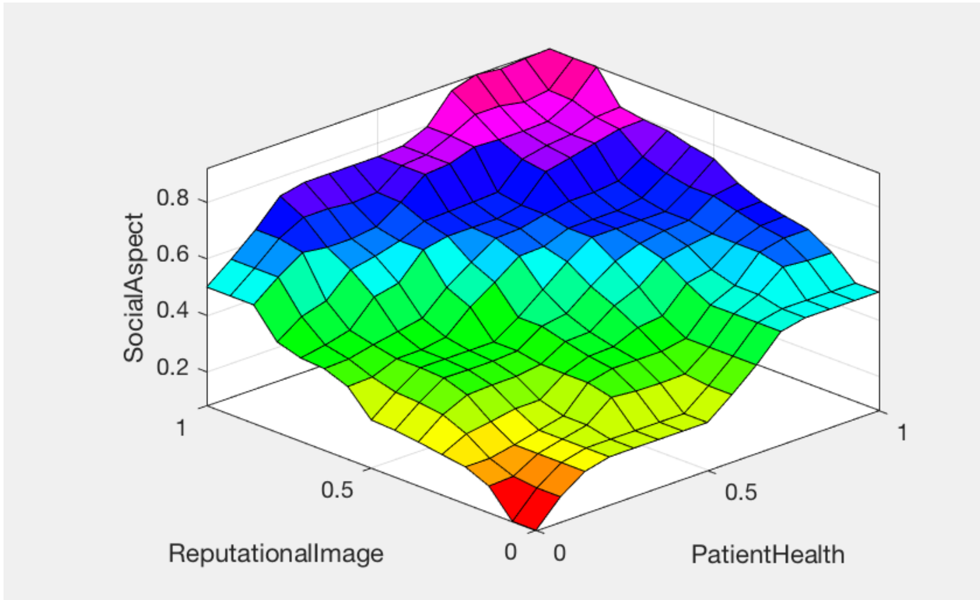


Figure 5-17: Surface of the FIS-L1-2

Figure 5-17 illustrates the surface of the social dimension after adding the reputational image to the output from the FIS_L1_1. The output's surface behavior is comparable to the output's surface of the previous subsystem with minor variance due to the difference between the membership functions. Similarly, the output is between 0.08 to 0.92. However, the distribution of the areas is different and the "Very High" area is wider compared to the FIS_L1_2.

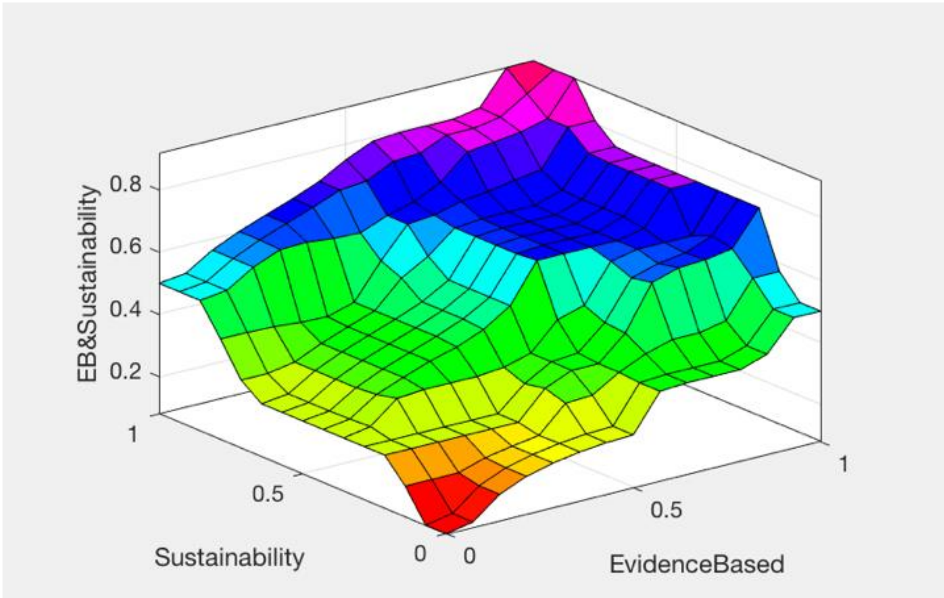


Figure 5-18: Surface of the FIS-L1-3

Figure 5-18 illustrates the relation between the inputs (sustainability and evidence based) and the output as the intermediate value that combined both inputs. The output surface also ranged between 0 and 0.92. The output has a proportional relation with the inputs, since the output increased if one of the inputs increased while holding the other input constant. However, the increment of change in both inputs yields to greater change in the output surface, which explains the several plateau planes in the surface.

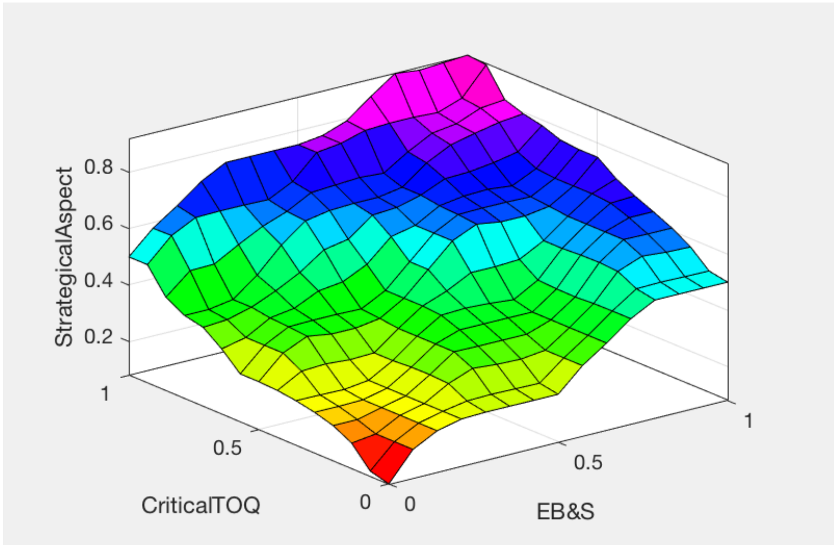


Figure 5-19: Surface of the FIS-L1-4

Figure 5-19 features the surface plot for the strategical dimension by combining two inputs (the output of FIS-L1-3 and the Critical to Quality). Similar to the other relationships, the inputs have a proportional relation with the output. However, it been noticed that to get higher output Critical to Quality should be at least 0.9 and the intermediate value scored at least 0.8.

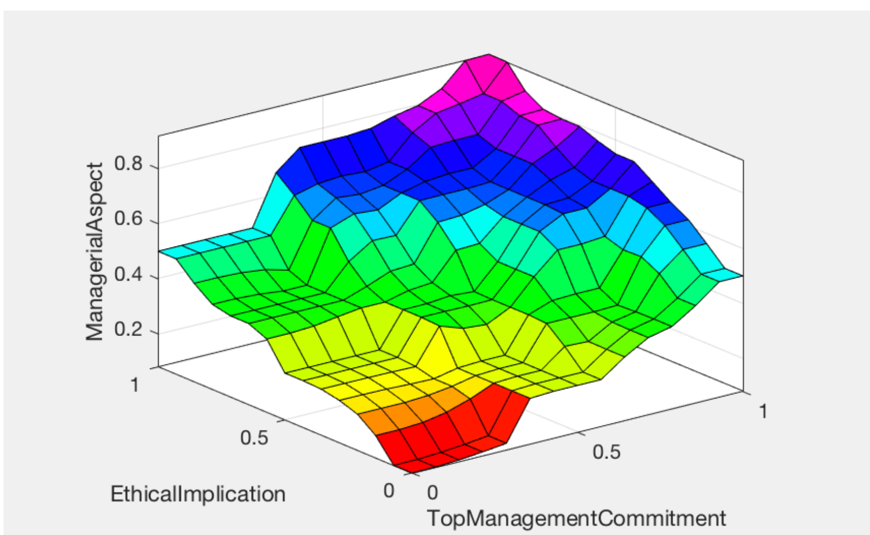


Figure 5-20: Surface of the FIS-L1-5

The surface plot in *Figure 5-20* represents the relationship between the ethical implications (input), Top management commitment (input), and the managerial dimension (output). Note that the complement of the ethical implications is the input of this FIS, since the goal is to select the improvement with fewest ethical implications. Thus, both inputs have a proportional relationship with the output. The plateau planes here are sharper than those for other FISs, which indicates the importance of increasing both inputs to get higher managerial dimension value.

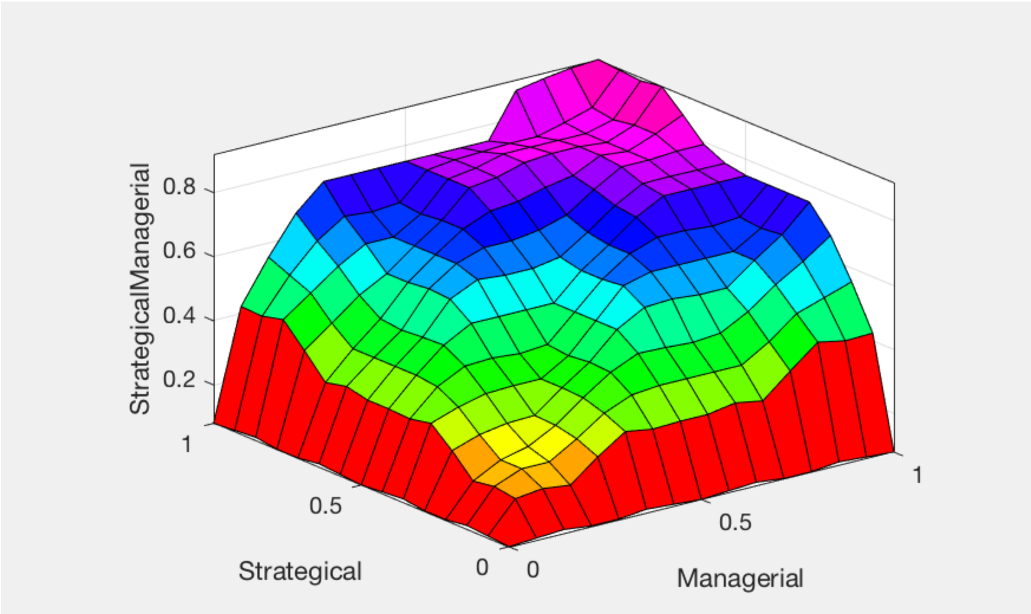


Figure 5-21: Surface of the FIS-L2

In Figure 5-21 the plateaus are more noticeable in the surface plot. The two inputs are (managerial and strategical dimensions value) from the earlier FISs, and the output is an intermediate value combining both inputs. The plot illustrates the output value increases by increasing both inputs. This means that even if one of the inputs was scored extremely high and the other input very low, the output would be very low.

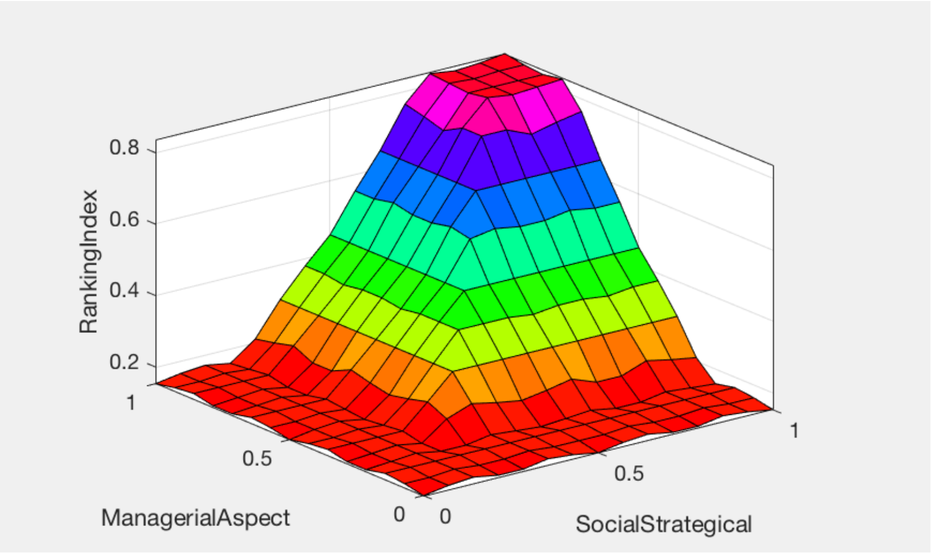


Figure 5-22: Surface of the FIS-L3

The last plot surface, in Figure 5-22, demonstrates the relationship between the prior FIS outputs (managerial /Strategical index and the social index) and the ranking index. The structure of the surface reveals that the ranking index value increases if both inputs are increased. Holding a low value for one of the inputs and increasing the other will not help to increase the ranking index. For instance, holding the managerial/strategical value around 0.2, no matter how the social index increases, the ranking index will be low. Both inputs should score more than 0.4 to start increasing the ranking index.

Table 5-62 presents the values for the social dimension, strategical dimension, managerial dimension and priority index after running the model for each alternative. The best-case scenario is that an alternative will have perfect expected performance in respect to all the evaluation factors, while the worst-case scenario is that an alternative will have the worst expected performance in respect to all the evaluation factors. Both cases were modeled to find the highest and lowest priority index, as the multi-defuzzification phases decrease the maximum outputs.

Table 5-62: Simulink results for each alternative for Hospital A

	Social index	**Strategical index**	**Managerial index**	**Priority index**	**Ranking**
Best case scenario	0.9145	0.9129	0.9200	0.8268	
Worst case scenario	0.1788	0.1885	0.0800	0.1657	
1a.	0.6250	0.2500	0.5000	0.4500	8
1b.	0.5464	0.5000	0.6885	0.5250	6
1c.	0.7500	0.2500	0.5664	0.4500	8
1d.	0.7695	0.6250	0.6347	0.6789	1
1e.	0.4257	0.3655	0.4126	0.3483	17
2a.	0.6311	0.4014	0.4126	0.3459	18
2b.	0.2500	0.3251	0.6073	0.1676	24
2c.	0.3682	0.3869	0.5908	0.3155	22
2d.	0.2500	0.5000	0.5908	0.1687	23
3a.	0.3750	0.4475	0.4150	0.3231	19
3b.	0.6380	0.4478	0.3835	0.3717	14
3c.	0.4554	0.4272	0.3126	0.3694	15
3d.	0.6582	0.6266	0.3750	0.6267	4
3e.	0.5198	0.5344	0.3750	0.4838	7
4a.	0.4266	0.6529	0.2380	0.3779	13
4b.	0.3750	0.7523	0.3750	0.3231	19
4c.	0.7553	0.658	0.5000	0.6635	2
4d.	0.5583	0.9055	0.6073	0.5374	5
4e.	0.4262	0.6071	0.4150	0.3683	16
5a.	0.6746	0.500	0.4126	0.4500	8
5b.	0.6424	0.6250	0.6204	0.6503	3
5c.	0.7350	0.2779	0.5000	0.4500	8
5d.	0.5692	0.2500	0.4447	0.3853	12
5e.	0.7993	0.3655	0.3750	0.3231	19

Based on the analysis, 1d is the most preferred improvement among the improvement opportunities, while 2b is the least preferred improvement. Multiple improvements have the same ranking index; the organization can choose from among those opportunities by linking it to the organization's strategy and objectives. For example, 1a, 1c, 5a, and 5c all have a 0.4500 priority index. Thus, to choose one over the others the organization can evaluate the strategical, managerial, and social indices; if the organization's goal is to improve the organization's social impact then 4c is the best alternatives between the four candidates.

5.6.2 Results for Hospital B

The rating of alternatives process was repeated again in Hospital B with the participation of three EFQM certified assessors. *Table 5-63*, *Table 5-64*, Table 5-65, *Table 5-66*, *Table 5-67*, and *Table 5-68*. present the linguistic variables for the expected performance for each alternative, the conversion of those variable into fuzzy numbers, the average fuzzy number for the evaluation, and the final fuzzy set when factor importance weight was considered, respectively. In this survey only three EFQM certified assessors participated, regardless of the reminder messages sent to the internal EFQM certified assessors within the hospital. Thus, in total only 432 ratings were collected, which aggregated to 144 average fuzzy numbers using the membership function in *Figure 4-10* and the fuzzy set in *Table 4-5*. The defuzzified numbers in Figure 5-23 were normalized (Table 5-70) to make the inputs adequate to create rules and serve as inputs to the model in Figure 5-23. The model consists of six inputs, six FISs, and one output. Four out of the six FISs are in the dimensions layer, one in the intermediate layer, and one in the integration layer. The sub-criterion (1.a) is used as an example in the figure, while the results for the other alternatives are presented in *Table 5-71*.

Table 5-63: EFQM sub-criteria ratings subject to the reputational image factor for Hospital B.

	Linguistic rating			Fuzzy numbers				
	CA-1	CA-2	CA-3	CA-1	CA-2	CA-3	Expected performance Average number	Expected performance Average number $*W_{factor}$
1a.	VH	H	H	[85,100,100]	[60,75,90]	[60,75,90]	[68.3,83.3,93.3]	[32.6,60.4,85.8]
1b.	H	M	VH	[60,75,90]	[35,50,65]	[85,100,100]	[60,75,85]	[28.6,54.4,78.2]
1c.	H	VH	VH	[60,75,90]	[85,100,100]	[85,100,100]	[76.7,91.7,96.7]	[36.6,66.5,89]
1d.	H	H	H	[60,75,90]	[60,75,90]	[60,75,90]	[60,75,90]	[28.6,54.4,82.8]
1e.	H	M	H	[60,75,90]	[35,50,65]	[60,75,90]	[51.7,66.7,81.7]	[24.6,48.4,75.2]
2a.	VH	H	M	[85,100,100]	[60,75,90]	[35,50,65]	[60,75,85]	[28.6,54.4,78.2]
2b.	H	L	M	[60,75,90]	[10,25,40]	[35,50,65]	[35,50,65]	[16.7,36.2,59.8]
2c.	H	VL	M	[60,75,90]	[0,0,15]	[35,50,65]	[31.7,41.7,56.7]	[15.1,30.2,52.2]
2d.	H	L	L	[60,75,90]	[10,25,40]	[10,25,40]	[26.7,41.7,56.7]	[12.7,30.2,52.2]
3a.	M	M	H	[35,50,65]	[35,50,65]	[60,75,90]	[43.3,58.3,73.3]	[20.6,42.3,67.4]
3b.	H	H	L	[60,75,90]	[60,75,90]	[10,25,40]	[43.3,58.3,73.3]	[20.6,42.3,67.4]
3c.	M	H	M	[35,50,65]	[60,75,90]	[35,50,65]	[43.3,58.3,73.3]	[20.6,42.3,67.4]
3d.	M	VL	M	[35,50,65]	[0,0,15]	[35,50,65]	[23.3,33.3,48.3]	[11.1,24.1,44.4]
3e.	M	M	H	[35,50,65]	[35,50,65]	[60,75,90]	[43.3,58.3,73.3]	[20.6,42.3,67.4]
4a.	H	VH	M	[60,75,90]	[85,100,100]	[35,50,65]	[60,75,85]	[28.6,54.4,78.2]
4b.	H	M	M	[60,75,90]	[35,50,65]	[35,50,65]	[43.3,58.3,73.3]	[20.6,42.3,67.4]
4c.	M	L	L	[35,50,65]	[10,25,40]	[10,25,40]	[18.3,33.3,48.3]	[8.7,24.1,44.4]
4d.	H	L	M	[60,75,90]	[10,25,40]	[35,50,65]	[35,50,65]	[16.7,36.2,59.8]
4e.	M	L	L	[35,50,65]	[10,25,40]	[10,25,40]	[18.3,33.3,48.3]	[8.7,24.1,44.4]
5a.	H	H	M	[60,75,90]	[60,75,90]	[35,50,65]	[51.7,66.7,81.7]	[24.6,48.4,75.2]
5b.	VH	H	L	[85,100,100]	[60,75,90]	[10,25,40]	[51.7,66.7,76.7]	[24.6,48.4,70.6]
5c.	M	H	H	[35,50,65]	[60,75,90]	[60,75,90]	[51.7,66.7,81.7]	[24.6,48.4,75.2]
5d.	H	M	H	[60,75,90]	[35,50,65]	[60,75,90]	[51.7,66.7,81.7]	[24.6,48.4,75.2]
5e.	H	VH	H	[60,75,90]	[85,100,100]	[60,75,90]	[68.3,83.3,93.3]	[32.6,60.4,85.8]

Table 5-64: EFQM sub-criteria ratings subject to the health and safety factor for Hospital B.

	Linguistic rating			Fuzzy numbers				
	CA-1	CA-2	CA-3	CA-1	CA-2	CA-3	Expected performance Average number	Expected performance Average number $*W_{factor}$
1a.	VL	L	L	[0,0,15]	[10,25,40]	[10,25,40]	[6.7,16.7,31.7]	[3.3,12.5,28.8]
1b.	VL	H	L	[0,0,15]	[60,75,90]	[10,25,40]	[23.3,33.3,48.3]	[11.6,24.9,44]
1c.	M	M	L	[35,50,65]	[35,50,65]	[10,25,40]	[26.7,41.7,56.7]	[13.3,31.2,51.6]
1d.	M	M	L	[35,50,65]	[35,50,65]	[10,25,40]	[26.7,41.7,56.7]	[13.3,31.2,51.6]
1e.	L	L	M	[10,25,40]	[10,25,40]	[35,50,65]	[18.3,33.3,48.3]	[9.1,24.9,44]
2a.	M	H	M	[35,50,65]	[60,75,90]	[35,50,65]	[43.3,58.3,73.3]	[21.6,43.6,66.7]
2b.	VL	L	M	[0,0,15]	[10,25,40]	[35,50,65]	[15,25,40]	[7.5,18.7,36.4]
2c.	M	M	M	[35,50,65]	[35,50,65]	[35,50,65]	[35,50,65]	[17.5,37.4,59.1]
2d.	VL	H	H	[0,0,15]	[60,75,90]	[60,75,90]	[40,50,65]	[20,37.4,59.1]
3a.	VL	L	L	[0,0,15]	[10,25,40]	[10,25,40]	[6.7,16.7,31.7]	[3.3,12.5,28.8]
3b.	VL	M	H	[0,0,15]	[35,50,65]	[60,75,90]	[31.7,41.7,56.7]	[15.8,31.2,51.6]
3c.	L	L	H	[10,25,40]	[10,25,40]	[60,75,90]	[26.7,41.7,56.7]	[13.3,31.2,51.6]
3d.	VL	L	H	[0,0,15]	[10,25,40]	[60,75,90]	[23.3,33.3,48.3]	[11.6,24.9,44]
3e.	M	VL	H	[35,50,65]	[0,0,15]	[60,75,90]	[31.7,41.7,56.7]	[15.8,31.2,51.6]
4a.	VL	VL	H	[0,0,15]	[0,0,15]	[60,75,90]	[20,25,40]	[10,18.7,36.4]
4b.	VL	L	H	[0,0,15]	[10,25,40]	[60,75,90]	[23.3,33.3,48.3]	[11.6,24.9,44]
4c.	H	M	L	[60,75,90]	[35,50,65]	[10,25,40]	[35,50,65]	[17.5,37.4,59.1]
4d.	L	M	H	[10,25,40]	[35,50,65]	[60,75,90]	[35,50,65]	[17.5,37.4,59.1]
4e.	VL	M	H	[0,0,15]	[35,50,65]	[60,75,90]	[31.7,41.7,56.7]	[15.8,31.2,51.6]
5a.	L	H	M	[10,25,40]	[60,75,90]	[35,50,65]	[35,50,65]	[17.5,37.4,59.1]
5b.	M	M	L	[35,50,65]	[35,50,65]	[10,25,40]	[26.7,41.7,56.7]	[13.3,31.2,51.6]
5c.	L	L	H	[10,25,40]	[10,25,40]	[60,75,90]	[26.7,41.7,56.7]	[13.3,31.2,51.6]
5d.	M	M	H	[35,50,65]	[35,50,65]	[60,75,90]	[43.3,58.3,73.3]	[21.6,43.6,66.7]
5e.	L	L	H	[10,25,40]	[10,25,40]	[60,75,90]	[26.7,41.7,56.7]	[13.3,31.2,51.6]

Table 5-65: EFQM sub-criteria ratings subject to the sustainability factor for Hospital B.

	Linguistic rating			Fuzzy numbers				
	CA-1	CA-2	CA-3	CA-1	CA-2	CA-3	Expected performance Average number	Expected performance Average number *W_{factor}
1a.	M	H	H	[35,50,65]	[60,75,90]	[60,75,90]	[51.7,66.7,81.7]	[22.4,45.5,71.9]
1b.	M	M	H	[35,50,65]	[35,50,65]	[60,75,90]	[43.3,58.3,73.3]	[18.8,39.8,64.5]
1c.	M	L	M	[35,50,65]	[10,25,40]	[35,50,65]	[26.7,41.7,56.7]	[11.6,28.5,49.9]
1d.	M	M	H	[35,50,65]	[35,50,65]	[60,75,90]	[43.3,58.3,73.3]	[18.8,39.8,64.5]
1e.	M	H	M	[35,50,65]	[60,75,90]	[35,50,65]	[43.3,58.3,73.3]	[18.8,39.8,64.5]
2a.	M	M	H	[35,50,65]	[35,50,65]	[60,75,90]	[43.3,58.3,73.3]	[18.8,39.8,64.5]
2b.	M	M	H	[35,50,65]	[35,50,65]	[60,75,90]	[43.3,58.3,73.3]	[18.8,39.8,64.5]
2c.	M	VH	M	[35,50,65]	[85,100,100]	[35,50,65]	[51.7,66.7,76.7]	[22.4,45.5,67.5]
2d.	L	H	H	[10,25,40]	[60,75,90]	[60,75,90]	[43.3,58.3,73.3]	[18.8,39.8,64.5]
3a.	M	H	M	[35,50,65]	[60,75,90]	[35,50,65]	[43.3,58.3,73.3]	[18.8,39.8,64.5]
3b.	L	L	M	[10,25,40]	[10,25,40]	[35,50,65]	[18.3,33.3,48.3]	[7.9,22.7,42.5]
3c.	M	M	L	[35,50,65]	[35,50,65]	[10,25,40]	[26.7,41.7,56.7]	[11.6,28.5,49.9]
3d.	L	M	L	[10,25,40]	[35,50,65]	[10,25,40]	[18.3,33.3,48.3]	[7.9,22.7,42.5]
3e.	M	M	M	[35,50,65]	[35,50,65]	[35,50,65]	[35,50,65]	[15.2,34.1,57.2]
4a.	M	M	H	[35,50,65]	[35,50,65]	[60,75,90]	[43.3,58.3,73.3]	[18.8,39.8,64.5]
4b.	M	H	H	[35,50,65]	[60,75,90]	[60,75,90]	[51.7,66.7,81.7]	[22.4,45.5,71.9]
4c.	M	H	H	[35,50,65]	[60,75,90]	[60,75,90]	[51.7,66.7,81.7]	[22.4,45.5,71.9]
4d.	M	H	M	[35,50,65]	[60,75,90]	[35,50,65]	[43.3,58.3,73.3]	[18.8,39.8,64.5]
4e.	M	M	M	[35,50,65]	[35,50,65]	[35,50,65]	[35,50,65]	[15.2,34.1,57.2]
5a.	H	M	H	[60,75,90]	[35,50,65]	[60,75,90]	[51.7,66.7,81.7]	[22.4,45.5,71.9]
5b.	M	L	M	[35,50,65]	[10,25,40]	[35,50,65]	[26.7,41.7,56.7]	[11.6,28.5,49.9]
5c.	M	H	M	[35,50,65]	[60,75,90]	[35,50,65]	[43.3,58.3,73.3]	[18.8,39.8,64.5]
5d.	M	H	H	[35,50,65]	[60,75,90]	[60,75,90]	[51.7,66.7,81.7]	[22.4,45.5,71.9]
5e.	H	M	M	[60,75,90]	[35,50,65]	[35,50,65]	[43.3,58.3,73.3]	[18.8,39.8,64.5]

Table 5-66: EFQM sub-criteria rating subject to the patient satisfaction factor for Hospital B.

	Linguistic rating			Fuzzy numbers				
	CA-1	CA-2	CA-3	CA-1	CA-2	CA-3	Expected performance Average number	Expected performance Average number $*W_{factor}$
1a.	H	H	M	[60,75,90]	[60,75,90]	[35,50,65]	[51.7,66.7,81.7]	[24.7,48.4,74.3]
1b.	H	M	L	[60,75,90]	[35,50,65]	[10,25,40]	[35,50,65]	[16.7,36.3,59.1]
1c.	H	VH	L	[60,75,90]	[85,100,100]	[10,25,40]	[51.7,66.7,76.7]	[24.7,48.4,69.7]
1d.	H	M	M	[60,75,90]	[35,50,65]	[35,50,65]	[43.3,58.3,73.3]	[20.7,42.3,66.6]
1e.	H	M	M	[60,75,90]	[35,50,65]	[35,50,65]	[43.3,58.3,73.3]	[20.7,42.3,66.6]
2a.	H	VH	M	[60,75,90]	[85,100,100]	[35,50,65]	[60,75,85]	[28.7,54.5,77.3]
2b.	M	VL	L	[35,50,65]	[0,0,15]	[10,25,40]	[15,25,40]	[7.2,18.2,36.4]
2c.	H	L	H	[60,75,90]	[10,25,40]	[60,75,90]	[43.3,58.3,73.3]	[20.7,42.3,66.6]
2d.	H	M	M	[60,75,90]	[35,50,65]	[35,50,65]	[43.3,58.3,73.3]	[20.7,42.3,66.6]
3a.	H	M	H	[60,75,90]	[35,50,65]	[60,75,90]	[51.7,66.7,81.7]	[24.7,48.4,74.3]
3b.	VH	L	M	[85,100,100]	[10,25,40]	[35,50,65]	[43.3,58.3,68.3]	[20.7,42.3,62.1]
3c.	VH	VL	M	[85,100,100]	[0,0,15]	[35,50,65]	[40,50,60]	[19.1,36.3,54.5]
3d.	VH	VL	M	[85,100,100]	[0,0,15]	[35,50,65]	[40,50,60]	[19.1,36.3,54.5]
3e.	H	VL	H	[60,75,90]	[0,0,15]	[60,75,90]	[40,50,65]	[19.1,36.3,59.1]
4a.	M	L	L	[35,50,65]	[10,25,40]	[10,25,40]	[18.3,33.3,48.3]	[8.7,24.2,43.9]
4b.	M	VL	H	[35,50,65]	[0,0,15]	[60,75,90]	[31.7,41.7,56.7]	[15.2,30.3,51.5]
4c.	H	VL	H	[60,75,90]	[0,0,15]	[60,75,90]	[40,50,65]	[19.1,36.3,59.1]
4d.	M	L	H	[35,50,65]	[10,25,40]	[60,75,90]	[35,50,65]	[16.7,36.3,59.1]
4e.	H	L	M	[60,75,90]	[10,25,40]	[35,50,65]	[35,50,65]	[16.7,36.3,59.1]
5a.	VH	L	H	[85,100,100]	[10,25,40]	[60,75,90]	[51.7,66.7,76.7]	[24.7,48.4,69.7]
5b.	VH	VH	H	[85,100,100]	[85,100,100]	[60,75,90]	[76.7,91.7,96.7]	[36.7,66.6,87.9]
5c.	H	VH	H	[60,75,90]	[85,100,100]	[60,75,90]	[68.3,83.3,93.3]	[32.7,60.5,84.8]
5d.	H	VH	H	[60,75,90]	[85,100,100]	[60,75,90]	[68.3,83.3,93.3]	[32.7,60.5,84.8]
5e.	VH	VH	H	[85,100,100]	[85,100,100]	[60,75,90]	[76.7,91.7,96.7]	[36.7,66.6,87.9]

Table 5-67: EFQM sub-criteria ratings subject to the creativity and innovation factor for hospital B.

	Linguistic rating			Fuzzy numbers				
	CA-1	CA-2	CA-3	CA-1	CA-2	CA-3	Expected performance Average number	Expected performance Average number $*W_{factor}$
1a.	H	H	H	[60,75,90]	[60,75,90]	[60,75,90]	[60,75,90]	[24.5,49,77.9]
1b.	H	M	H	[60,75,90]	[35,50,65]	[60,75,90]	[51.7,66.7,81.7]	[21.1,43.6,70.7]
1c.	H	VH	H	[60,75,90]	[85,100,100]	[60,75,90]	[68.3,83.3,93.3]	[27.9,54.5,80.8]
1d.	H	M	VH	[60,75,90]	[35,50,65]	[85,100,100]	[60,75,85]	[24.5,49,73.6]
1e.	H	M	H	[60,75,90]	[35,50,65]	[60,75,90]	[51.7,66.7,81.7]	[21.1,43.6,70.7]
2a.	H	VH	H	[60,75,90]	[85,100,100]	[60,75,90]	[68.3,83.3,93.3]	[27.9,54.5,80.8]
2b.	M	VL	H	[35,50,65]	[0,0,15]	[60,75,90]	[31.7,41.7,56.7]	[12.9,27.3,49.1]
2c.	H	L	H	[60,75,90]	[10,25,40]	[60,75,90]	[43.3,58.3,73.3]	[17.7,38.1,63.4]
2d.	H	M	H	[60,75,90]	[35,50,65]	[60,75,90]	[51.7,66.7,81.7]	[21.1,43.6,70.7]
3a.	H	M	M	[60,75,90]	[35,50,65]	[35,50,65]	[43.3,58.3,73.3]	[17.7,38.1,63.4]
3b.	VH	L	H	[85,100,100]	[10,25,40]	[60,75,90]	[51.7,66.7,76.7]	[21.1,43.6,66.4]
3c.	VH	VL	M	[85,100,100]	[0,0,15]	[35,50,65]	[40,50,60]	[16.3,32.7,51.9]
3d.	VH	VL	M	[85,100,100]	[0,0,15]	[35,50,65]	[40,50,60]	[16.3,32.7,51.9]
3e.	H	VL	H	[60,75,90]	[0,0,15]	[60,75,90]	[40,50,65]	[16.3,32.7,56.3]
4a.	M	L	H	[35,50,65]	[10,25,40]	[60,75,90]	[35,50,65]	[14.3,32.7,56.3]
4b.	M	VL	M	[35,50,65]	[0,0,15]	[35,50,65]	[23.3,33.3,48.3]	[9.5,21.8,41.8]
4c.	H	VL	L	[60,75,90]	[0,0,15]	[10,25,40]	[23.3,33.3,48.3]	[9.5,21.8,41.8]
4d.	M	L	H	[35,50,65]	[10,25,40]	[60,75,90]	[35,50,65]	[14.3,32.7,56.3]
4e.	H	L	M	[60,75,90]	[10,25,40]	[35,50,65]	[35,50,65]	[14.3,32.7,56.3]
5a.	VH	L	H	[85,100,100]	[10,25,40]	[60,75,90]	[51.7,66.7,76.7]	[21.1,43.6,66.4]
5b.	VH	VH	H	[85,100,100]	[85,100,100]	[60,75,90]	[76.7,91.7,96.7]	[31.3,60,83.7]
5c.	H	VH	M	[60,75,90]	[85,100,100]	[35,50,65]	[60,75,85]	[24.5,49,73.6]
5d.	H	VH	H	[60,75,90]	[85,100,100]	[60,75,90]	[68.3,83.3,93.3]	[27.9,54.5,80.8]
5e.	VH	VH	M	[85,100,100]	[85,100,100]	[35,50,65]	[68.3,83.3,88.3]	[27.9,54.5,76.4]

Table 5-68: EFQM sub-criteria ratings subject to the resource and information availability factor for Hospital B.

	Linguistic rating			Fuzzy numbers				
	CA-1	CA-2	CA-3	CA-1	CA-2	CA-3	Expected performance Average number	Expected performance Average number *W_{factor}
1a.	H	L	L	[60,75,90]	[10,25,40]	[10,25,40]	[26.7,41.7,56.7]	[12.9,30.5,51]
1b.	VH	H	L	[85,100,100]	[60,75,90]	[10,25,40]	[51.7,66.7,76.7]	[24.9,48.8,69]
1c.	H	L	L	[60,75,90]	[10,25,40]	[10,25,40]	[26.7,41.7,56.7]	[12.9,30.5,51]
1d.	M	L	L	[35,50,65]	[10,25,40]	[10,25,40]	[18.3,33.3,48.3]	[8.8,24.4,43.4]
1e.	M	VH	M	[35,50,65]	[85,100,100]	[35,50,65]	[51.7,66.7,76.7]	[24.9,48.8,69]
2a.	VH	L	M	[85,100,100]	[10,25,40]	[35,50,65]	[43.3,58.3,68.3]	[20.9,42.7,61.4]
2b.	H	VH	M	[60,75,90]	[85,100,100]	[35,50,65]	[60,75,85]	[28.9,54.9,76.4]
2c.	H	L	M	[60,75,90]	[10,25,40]	[35,50,65]	[35,50,65]	[16.9,36.6,58.4]
2d.	H	H	H	[60,75,90]	[60,75,90]	[60,75,90]	[60,75,90]	[28.9,54.9,80.9]
3a.	H	VH	H	[60,75,90]	[85,100,100]	[60,75,90]	[68.3,83.3,93.3]	[32.9,61,83.9]
3b.	H	VH	L	[60,75,90]	[85,100,100]	[10,25,40]	[51.7,66.7,76.7]	[24.9,48.8,69]
3c.	H	H	M	[60,75,90]	[60,75,90]	[35,50,65]	[51.7,66.7,81.7]	[24.9,48.8,73.5]
3d.	H	M	M	[60,75,90]	[35,50,65]	[35,50,65]	[43.3,58.3,73.3]	[20.9,42.7,65.9]
3e.	H	M	M	[60,75,90]	[35,50,65]	[35,50,65]	[43.3,58.3,73.3]	[20.9,42.7,65.9]
4a.	M	L	M	[35,50,65]	[10,25,40]	[35,50,65]	[26.7,41.7,56.7]	[12.9,30.5,51]
4b.	M	H	L	[35,50,65]	[60,75,90]	[10,25,40]	[35,50,65]	[16.9,36.6,58.4]
4c.	H	VH	H	[60,75,90]	[85,100,100]	[60,75,90]	[68.3,83.3,93.3]	[32.9,61,83.9]
4d.	H	VH	M	[60,75,90]	[85,100,100]	[35,50,65]	[60,75,85]	[28.9,54.9,76.4]
4e.	H	M	H	[60,75,90]	[35,50,65]	[60,75,90]	[51.7,66.7,81.7]	[24.9,48.8,73.5]
5a.	M	L	M	[35,50,65]	[10,25,40]	[35,50,65]	[26.7,41.7,56.7]	[12.9,30.5,51]
5b.	H	L	L	[60,75,90]	[10,25,40]	[10,25,40]	[26.7,41.7,56.7]	[12.9,30.5,51]
5c.	M	L	M	[35,50,65]	[10,25,40]	[35,50,65]	[26.7,41.7,56.7]	[12.9,30.5,51]
5d.	M	H	H	[35,50,65]	[60,75,90]	[60,75,90]	[51.7,66.7,81.7]	[24.9,48.8,73.5]
5e.	M	L	M	[35,50,65]	[10,25,40]	[35,50,65]	[26.7,41.7,56.7]	[12.9,30.5,51]

Table 5-69: Improvements' expected performance crisp values for Hospital B.

	Patient satisfaction	Health and safety	Reputational image	Sustainability	Creativity and innovation	Resource and information availability
1a.	49.13	14.87	59.60	46.60	50.47	31.47
1b.	37.37	26.83	53.73	41.03	45.13	47.57
1c.	47.60	32.03	64.03	30.00	54.40	31.47
1d.	43.20	32.03	55.27	41.03	49.03	25.53
1e.	43.20	26.00	49.40	41.03	45.13	47.57
2a.	53.50	43.97	53.73	41.03	54.40	41.67
2b.	20.60	20.87	37.57	41.03	29.77	53.40
2c.	43.20	38.00	32.50	45.13	39.73	37.30
2d.	43.20	38.83	31.70	41.03	45.13	54.90
3a.	49.13	14.87	43.43	41.03	39.73	59.27
3b.	41.70	32.87	43.43	24.37	43.70	47.57
3c.	36.63	32.03	43.43	30.00	33.63	49.07
3d.	36.63	26.83	26.53	24.37	33.63	43.17
3e.	38.17	32.87	43.43	35.50	35.10	43.17
4a.	25.60	21.70	53.73	41.03	34.43	31.47
4b.	32.33	26.83	43.43	46.60	24.37	37.30
4c.	38.17	38.00	25.73	46.60	24.37	59.27
4d.	37.37	38.00	37.57	41.03	34.43	53.40
4e.	37.37	32.87	25.73	35.50	34.43	49.07
5a.	47.60	38.00	49.40	46.60	43.70	31.47
5b.	63.73	32.03	47.87	30.00	58.33	31.47
5c.	59.33	32.03	49.40	41.03	49.03	31.47
5d.	59.33	43.97	49.40	46.60	54.40	49.07
5e	63.73	32.03	59.60	41.03	52.93	31.47

Table 5-70: Improvements' expected performance after normalization for Hospital B.

	Patient satisfaction	Health and safety	Reputational image	Sustainability	Creativity and innovation	Resource and information availability
1a.	0.66	0.00	0.88	1.00	0.77	0.18
1b.	0.39	0.41	0.73	0.75	0.61	0.65
1c.	0.63	0.59	1.00	0.25	0.88	0.18
1d.	0.52	0.59	0.77	0.75	0.73	0.00
1e.	0.52	0.38	0.62	0.75	0.61	0.65
2a.	0.76	1.00	0.73	0.75	0.88	0.48
2b.	0.00	0.21	0.31	0.75	0.16	0.83
2c.	0.52	0.79	0.18	0.93	0.45	0.35
2d.	0.52	0.82	0.16	0.75	0.61	0.87
3a.	0.66	0.00	0.46	0.75	0.45	1.00
3b.	0.49	0.62	0.46	0.00	0.57	0.65
3c.	0.37	0.59	0.46	0.25	0.27	0.70
3d.	0.37	0.41	0.02	0.00	0.27	0.52
3e.	0.41	0.62	0.46	0.50	0.32	0.52
4a.	0.12	0.23	0.73	0.75	0.30	0.18
4b.	0.27	0.41	0.46	1.00	0.00	0.35
4c.	0.41	0.79	0.00	1.00	0.00	1.00
4d.	0.39	0.79	0.31	0.75	0.30	0.83
4e.	0.39	0.62	0.00	0.50	0.30	0.70
5a.	0.63	0.79	0.62	1.00	0.57	0.18
5b.	1.00	0.59	0.58	0.25	1.00	0.18
5c.	0.90	0.59	0.62	0.75	0.73	0.18
5d.	0.90	1.00	0.62	1.00	0.88	0.70
5e	1.00	0.59	0.88	0.75	0.84	0.18

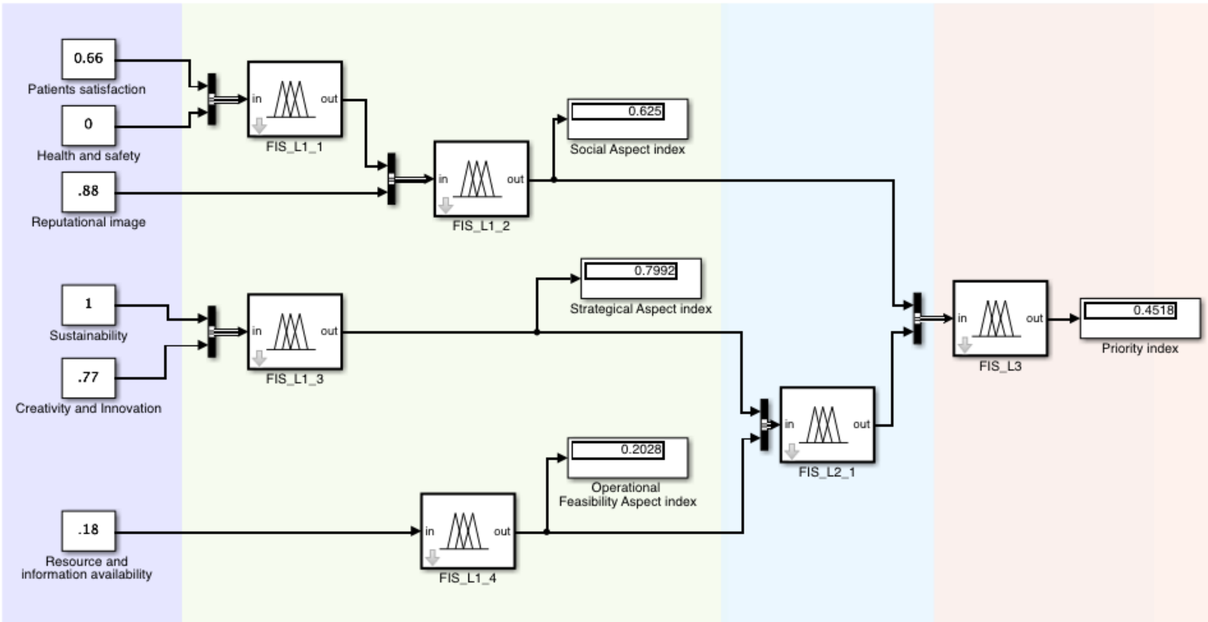


Figure 5-23: Implementation of the ranking model using Simulink- Hospital B

The FISs were built using the Fuzzy Logic Toolbox in MATLAB (R2018b). Each FIS contains the membership function acquired from the experts' knowledge acquisition step and the created rules discussed in chapter 4. This section presents a series of 3D surface plots for the subsystem. Only FIS-L1-3 and FIS-L1-4 were obtained since the other plots are the same as those obtained for hospital A, which are presented in an earlier section.

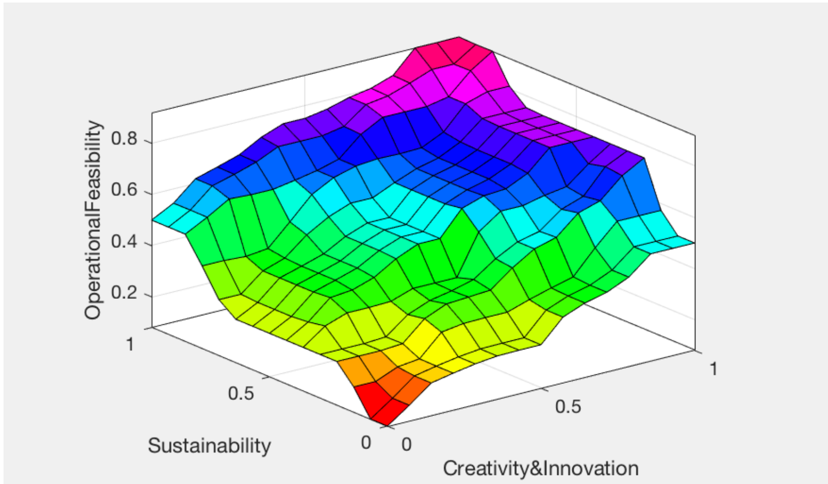


Figure 5-24: FIS-L1-3 Surface plot- Hospital B

The surface plot in Figure 5-24 demonstrates the relationship between the creativity and innovation factor, the sustainability factor, and the resultant strategical index. The output increases proportionally with an increase in both inputs. The plot shows that the maximum value for the strategical index will be one if one of the inputs are held to zero, no matter the value of the second input. Thus, obtaining a high value for the strategical index requires increasing both inputs.

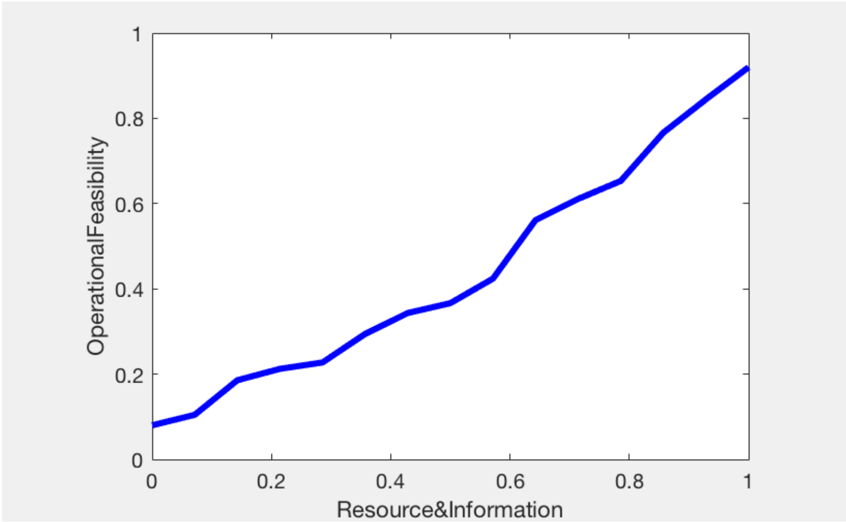


Figure 5-25: FIS-L1-4 Surface plot- Hospital B

There is only one input in the operational feasibility dimension, thus the plot (Figure 5-25) only illustrates the relation between one input (resource and information availability) and one output (operational feasibility index). The plot confirms the linear relationship between the input and the output.

After running the Simulink for each alternative, the values of the social index, strategical index, managerial index, and priority index were established for each alternative. The Simulink results are presented in Table 5-71. The priority index for the best-case scenario is 0.8268 while the priority index for the worst-case scenario is 0.1657. The priority indices for the proposed alternatives are between those two values.

Table 5-71 illustrates that 2a has the highest priority index whereas 3d had the lowest priority index. When multiple improvements have the same ranking index, the organization can choose between those opportunities based on the other indices by linking them to the organization's strategy and objectives. For example, 3a and 3c have a 0.3231 priority index. Thus, to make a choice of one over the others the organization can evaluate the strategical, operational feasibility, and social indices. For instance, if the organization's goal is to improve the organization strategical impact then 3a is a better candidate.

Table 5-71: Simulink's result for each alternative for Hospital B.

	Social index	**Strategical index**	**Operational feasibility index**	**Priority index**	**Ranking**
Best case scenario	0.9145	0.9200	0.9200	0.8268	
Worst case scenario	0.1788	0.0800	0.0800	0.1657	
1a.	0.6250	0.7992	0.2028	0.4518	5
1b.	0.6246	0.6571	0.5687	0.6261	2
1c.	0.7538	0.6156	0.2028	0.3806	10
1d.	0.6397	0.6602	0.0800	0.2698	20
1e.	0.5128	0.6571	0.5687	0.4747	4
2a.	0.7522	0.7806	0.3622	0.6131	3
2b.	0.2972	0.4516	0.7137	0.2300	22
2c.	0.3601	0.75	0.2876	0.3061	19
2d.	0.3721	0.6571	0.7727	0.3198	18
3a.	0.3750	0.6523	0.9200	0.3231	15
3b.	0.4671	0.25	0.5687	0.4181	6
3c.	0.3750	0.2942	0.6041	0.3231	15
3d.	0.2500	.25	0.3726	0.1733	23
3e.	0.3888	0.393	0.3726	0.3332	14
4a.	0.4886	0.5583	0.2028	0.3908	9
4b.	0.3750	0.5	0.2876	0.3231	15
4c.	0.3050	0.5	0.9200	0.2368	21
4d.	0.4464	0.5583	0.7137	0.3978	7
4e.	0.2500	0.3959	0.6041	0.1706	24
5a.	0.6175	0.75	0.2028	0.3794	11
5b.	0.6253	0.6557	0.2028	0.3709	13
5c.	0.6267	0.6602	0.2028	0.3723	12
5d.	0.7060	0.9124	0.6041	0.7494	1
5e.	0.7899	0.7365	0.2028	0.3918	8

5.7 Reliability and Validation test

The reliability of the collected data from the FDM phase was investigated using SPSS (Table 5-72). The values for Cronbach's alpha, CITC, and Cronbach's alpha if item deleted were calculated to test the sample internal consistency. The reliability analysis below shows that the Cronbach's alpha value was 0.977 (greater than 0.7), which indicates high reliability. The CITC values for all of the items were greater than 0.3, indicating a high correlation of each item with the overall questionnaire. As Cronbach's alpha if item deleted values did not demonstrate any major change from the original Cronbach's alpha, this indicates that all items should be included in the construct. The reliability analysis showed that the instruments reached an acceptable level of reliability.

Face validity testing was first carried with the participation of two groups. The first entities were familiar with the topic and evaluated the surveys' technical content. Then in the qualitative method, face-to-face interviews were carried out with the academic adviser, mentor from the health authority, and master examiner with Florida sterling council to validate the content of the instrument. The second entity focused on the survey's language readability and clarity; this evaluation was conducted by a professional language service.

Second, the instruments' contents validity was tested through the first round of FDM. The first round asked the participants to review the survey items based on their personal experience and provide feedback.

Before testing the construct validity, data suitability for the analysis was tested through performing factor KMO measures of sampling adequacy and Bartlett's test of sphericity. The

KMO was equal to 0.966, which is greater than the minimum acceptable value (0.6). Bartlett's test of sphericity was found to be significant ($P < 0.05$). Thus, factor analysis was considered to be appropriate for data analysis.

Under factor analysis, varimax rotation and eigenvalues greater than one were applied to calculate the factor loading. The analysis displayed in Table 5-72 show that all elements have a factor loading greater than 0.3, which indicates an acceptable construct of the instrument.

Table 5-72: Reliability analysis and factor analysis.

Variable	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Loading factor	Scale Statistics
C1	0.798	0.976	0.681	▪ Cronbach's Alpha = 0.977 ▪ Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.966 ▪ Bartlett's test of sphericity: Chi-Square= 8428.8 Significance level: 0.000
C2	0.748	0.977	0.585	
C3	0.676	0.977	0.572	
C4	0.767	0.976	0.620	
C5	0.803	0.976	0.708	
C6	0.733	0.977	0.598	
C7	0.760	0.977	0.688	
C8	0.615	0.977	0.484	
C9	0.638	0.977	0.561	
C10	0.791	0.976	0.644	
C11	0.817	0.976	0.682	
C12	0.796	0.976	0.658	
C13	0.770	0.976	0.615	
C14	0.820	0.976	0.722	
C15	0.825	0.976	0.704	
C16	0.814	0.976	0.703	
C17	0.801	0.976	0.688	
C18	0.771	0.976	0.611	
C19	0.823	0.976	0.710	
C20	0.786	0.976	0.638	
C21	0.780	0.976	0.656	

Variable	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Loading factor	Scale Statistics
C22	0.754	0.977	0.617	
C23	0.796	0.976	0.679	
C24	0.814	0.976	0.715	
C25	0.828	0.976	0.703	
C26	0.682	0.977	0.486	
C27	0.771	0.976	0.619	
C28	0.798	0.976	0.653	

Based on the data from hospital A, Fuzzy VIKOR was implemented to compare its outcome with the framework's results. The factors weight found from FDM analysis were utilized in F-VIKOR as well for the factors weight. The other inputs for F-VIKOR were the alternatives expected performance based on the EFQM assessors rating. The linguistic ratings were fuzzified and the fuzzy expected performance average numbers were computed. Then, the performance rating matrix was constructed, where each element represents the fuzzy expected performance with respect to j criteria. The performance matrix was normalized using Eq.(23) and Eq.(24) as shown in Table 5-73. The next step was to measure the fuzzy distance between the alternative and fuzzy best value, the distance between the alternative and the fuzzy worst value, as well as the fuzzy compromise solution using Eq.(25), Eq. (26) and Eq.(27), respectively. Then, the fuzzy numbers were defuzzied to obtain the crisp values for the S, R, and Q. Finally, alternatives were sorted by the value of Q in ascending order as shown in Table 5-74. Notice that alternatives with smaller Q value are preferred.

Table 5-73: FVIKOR performance matrix after normalization for Hospital A

	Patient satisfaction	Health and safety	Reputational image	Sustainability	Evidence based	Critical to Quality	Top management commitment	Ethical implications
1a.	[0.33,0.31,0.13]	[0.51,0.67,0.62]	[0.19,0.13,0.04]	[0.36,0.33,0.19]	[0.43,0.52,0.42]	[0.18,0.05,0]	[0.33,0.67,0.89]	[0.33,0.31,0.13]
1b.	[0.33,0.31,0.18]	[0.31,0.3,0.21]	[0.29,0.29,0.16]	[0.36,0.33,0.13]	[0.34,0.33,0.19]	[0.23,0.12,0.03]	[0.11,0.33,0.64]	[0.33,0.31,0.18]
1c.	[0.25,0.17,0.07]	[0.38,0.41,0.3]	[0.12,0.03,0]	[0.36,0.33,0.19]	[0.46,0.52,0.42]	[0.23,0.12,0.03]	[0.18,0.45,0.78]	[0.25,0.17,0.07]
1d.	[0.29,0.24,0.1]	[0.31,0.3,0.18]	[0.16,0.08,0.05]	[0.31,0.25,0.1]	[0.34,0.33,0.19]	[0.28,0.2,0.06]	[0.07,0.28,0.57]	[0.29,0.24,0.1]
1e.	[0.42,0.44,0.3]	[0.31,0.3,0.18]	[0.29,0.29,0.16]	[0.4,0.4,0.23]	[0.34,0.33,0.19]	[0.38,0.35,0.12]	[0.11,0.33,0.64]	[0.42,0.44,0.3]
2a.	[0.33,0.31,0.18]	[0.34,0.35,0.28]	[0.22,0.19,0.06]	[0.31,0.25,0.04]	[0.3,0.27,0.16]	[0.38,0.35,0.12]	[0.11,0.33,0.64]	[0.33,0.31,0.18]
2b.	[0.42,0.44,0.3]	[0.41,0.46,0.36]	[0.46,0.55,0.39]	[0.36,0.33,0.19]	[0.38,0.4,0.27]	[0.33,0.27,0.09]	[0.07,0.28,0.57]	[0.42,0.44,0.3]
2c.	[0.42,0.44,0.35]	[0.31,0.3,0.21]	[0.39,0.45,0.31]	[0.26,0.18,0.11]	[0.34,0.33,0.24]	[0.28,0.2,0.06]	[0.11,0.33,0.59]	[0.42,0.44,0.35]
2d.	[0.47,0.5,0.43]	[0.34,0.35,0.28]	[0.42,0.5,0.37]	[0.21,0.1,0.02]	[0.38,0.4,0.31]	[0.28,0.2,0.06]	[0.11,0.33,0.59]	[0.47,0.5,0.43]
3a.	[0.38,0.37,0.26]	[0.31,0.3,0.21]	[0.32,0.34,0.21]	[0.36,0.33,0.19]	[0.34,0.33,0.24]	[0.38,0.35,0.16]	[0.11,0.33,0.59]	[0.38,0.37,0.26]
3b.	[0.33,0.31,0.18]	[0.17,0.09,0]	[0.26,0.24,0.14]	[0.36,0.33,0.19]	[0.3,0.27,0.2]	[0.33,0.27,0.13]	[0.15,0.39,0.62]	[0.33,0.31,0.18]
3c.	[0.33,0.31,0.23]	[0.24,0.2,0.13]	[0.36,0.39,0.26]	[0.4,0.4,0.29]	[0.34,0.33,0.24]	[0.43,0.42,0.23]	[0.15,0.39,0.62]	[0.33,0.31,0.23]
3d.	[0.29,0.24,0.15]	[0.17,0.09,0]	[0.26,0.24,0.11]	[0.36,0.33,0.19]	[0.3,0.27,0.16]	[0.38,0.35,0.16]	[0.18,0.45,0.69]	[0.29,0.24,0.15]
3e.	[0.4,0.44,0.4]	[0.27,0.25,0.19]	[0.26,0.24,0.14]	[0.45,0.47,0.32]	[0.38,0.4,0.27]	[0.38,0.35,0.16]	[0.18,0.45,0.69]	[0.4,0.44,0.4]
4a.	[0.38,0.37,0.26]	[0.31,0.3,0.21]	[0.29,0.29,0.16]	[0.26,0.18,0.11]	[0.26,0.21,0.13]	[0.43,0.42,0.23]	[0.22,0.5,0.76]	[0.38,0.37,0.26]
4b.	[0.48,0.57,0.51]	[0.24,0.2,0.13]	[0.3,0.34,0.24]	[0.26,0.18,0.06]	[0.22,0.15,0.05]	[0.38,0.35,0.2]	[0.07,0.28,0.57]	[0.48,0.57,0.51]
4c.	[0.29,0.24,0.1]	[0.17,0.09,0]	[0.22,0.19,0.06]	[0.26,0.18,0]	[0.3,0.27,0.11]	[0.43,0.42,0.19]	[0,0.17,0.42]	[0.29,0.24,0.1]
4d.	[0.33,0.31,0.18]	[0.24,0.2,0.09]	[0.32,0.34,0.21]	[0.26,0.18,0]	[0.22,0.15,0]	[0.33,0.27,0.09]	[0.07,0.28,0.52]	[0.33,0.31,0.18]
4e.	[0.38,0.37,0.26]	[0.27,0.25,0.15]	[0.32,0.34,0.21]	[0.31,0.25,0.1]	[0.26,0.21,0.08]	[0.38,0.35,0.16]	[0.11,0.33,0.59]	[0.38,0.37,0.26]
5a.	[0.33,0.31,0.23]	[0.27,0.25,0.15]	[0.19,0.13,0.07]	[0.36,0.33,0.13]	[0.34,0.33,0.19]	[0.38,0.35,0.12]	[0.11,0.33,0.64]	[0.33,0.31,0.23]
5b.	[0.2,0.11,0.03]	[0.27,0.25,0.15]	[0.22,0.19,0.09]	[0.31,0.25,0.1]	[0.3,0.27,0.16]	[0.33,0.27,0.09]	[0.04,0.22,0.5]	[0.2,0.11,0.03]
5c.	[0.29,0.24,0.15]	[0.31,0.3,0.18]	[0.19,0.13,0.04]	[0.36,0.33,0.13]	[0.38,0.4,0.27]	[0.48,0.5,0.26]	[0,0.17,0.42]	[0.29,0.24,0.15]
5d.	[0.33,0.31,0.18]	[0.38,0.41,0.3]	[0.26,0.24,0.14]	[0.45,0.47,0.32]	[0.34,0.33,0.19]	[0.43,0.42,0.19]	[0.04,0.22,0.5]	[0.33,0.31,0.18]
5e	[0.33,0.31,0.13]	[0.51,0.67,0.62]	[0.19,0.13,0.04]	[0.36,0.33,0.19]	[0.43,0.52,0.42]	[0.18,0.05,0]	[0.33,0.67,0.89]	[0.33,0.31,0.13]

Table 5-74: FVIKOR indices and alternatives ranking for Hospital A

Alternative	Fuzzy S	Fuzzy R	Fuzzy Q	S	R	Q	Rank
1a.	[2.74,3.12,2.53]	[0.51,0.67,0.89]	[0.94,0.98,1]	2.8	0.69	0.97	24
1b.	[2.3,2.32,1.69]	[0.36,0.33,0.64]	[0.28,0.26,0.46]	2.1	0.44	0.33	6
1c.	[2.35,2.41,1.97]	[0.46,0.52,0.78]	[0.59,0.53,0.7]	2.24	0.59	0.61	20
1d.	[2.09,1.99,1.36]	[0.34,0.33,0.57]	[0.11,0.14,0.28]	1.81	0.41	0.18	4
1e.	[2.62,2.82,2]	[0.42,0.44,0.64]	[0.63,0.58,0.56]	2.48	0.50	0.59	18
2a.	[2.36,2.43,1.66]	[0.38,0.38,0.64]	[0.37,0.37,0.46]	2.15	0.47	0.4	10
2b.	[2.84,3.17,2.41]	[0.46,0.55,0.57]	[0.86,0.85,0.62]	2.81	0.53	0.78	23
2c.	[2.48,2.61,2.08]	[0.42,0.45,0.59]	[0.55,0.52,0.54]	2.39	0.49	0.54	15
2d.	[2.62,2.82,2.34]	[0.47,0.5,0.59]	[0.77,0.66,0.62]	2.59	0.52	0.68	22
3a.	[2.53,2.66,2.01]	[0.38,0.37,0.59]	[0.46,0.44,0.51]	2.4	0.45	0.47	12
3b.	[2.23,2.21,1.61]	[0.36,0.39,0.62]	[0.24,0.3,0.42]	2.02	0.46	0.32	5
3c.	[2.53,2.69,2.13]	[0.43,0.42,0.62]	[0.6,0.51,0.58]	2.45	0.49	0.56	16
3d.	[2.18,2.15,1.52]	[0.38,0.45,0.69]	[0.27,0.35,0.46]	1.95	0.51	0.36	7
3e.	[2.56,2.78,2.23]	[0.45,0.47,0.69]	[0.68,0.61,0.69]	2.52	0.54	0.66	21
4a.	[2.43,2.52,1.95]	[0.43,0.5,0.76]	[0.55,0.55,0.68]	2.3	0.56	0.59	18
4b.	[2.19,2.25,1.82]	[0.48,0.57,0.57]	[0.55,0.54,0.43]	2.09	0.54	0.51	13
4c.	[1.95,1.81,0.97]	[0.43,0.42,0.42]	[0.28,0.19,0]	1.58	0.42	0.16	3
4d.	[1.97,1.85,1.09]	[0.33,0.34,0.52]	[0.01,0.1,0.14]	1.64	0.40	0.08	2
4e.	[2.36,2.41,1.7]	[0.38,0.37,0.59]	[0.37,0.35,0.41]	2.16	0.45	0.38	9
5a.	[2.31,2.34,1.68]	[0.38,0.35,0.64]	[0.34,0.29,0.46]	2.11	0.46	0.36	7
5b.	[1.95,1.81,1.21]	[0.33,0.27,0.5]	[0,0,0.16]	1.66	0.37	0.05	1
5c.	[2.46,2.58,1.75]	[0.48,0.51,0.42]	[0.7,0.58,0.25]	2.26	0.47	0.51	13
5d.	[2.6,2.78,2]	[0.45,0.47,0.5]	[0.7,0.61,0.42]	2.46	0.47	0.58	17
5e	[2.31,2.34,1.73]	[0.43,0.42,0.64]	[0.48,0.38,0.48]	2.13	0.50	0.45	11

To compare the similarity between the two rankings, Spearmen coefficient ranking was computed using Eq.(47) to test the following hypothesis.

Null hypothesis (H_0): There is no statically significant relationship between the alternatives ranking order using FIS and the alternatives ranking order using F-VIKOR.

Alternative hypothesis (H_1): There is a statically significant relationship between the alternatives ranking order using FIS and the alternatives ranking order using F-VIKOR.

SPSS showed that r_s = 0.520 and p-value =0.009. Comparing those values with the critical value of the Spearman's ranked correlation coefficient =0.406 (for n= 24, alpha= 0.05). Thus, the null hypothesis is rejected and there is a similarity between the two rankings.

The same process was repeated to find the Spearman's ranked correlation coefficient in between FIS results and FVIKOR for Hospital B. *Table 5-75* illustrates the performance matrix after the normalization and *Table 5-76* shows the results of FVIKOR calculations. The similarity between the two rankings was compared using the Spearmen coefficient ranking.

SPSS showed that r_s = 0.679 and p-value =0.000. Comparing those values with the critical value of the Spearman's ranked correlation coefficient =0.406 (for n= 24, alpha= 0.05). Thus, the null hypothesis is rejected and there is a similarity between the two rankings. Spearmen coefficient value of 0.679; between 0.6-0.79; indicates a strong relationship between the two rankings.

Table 5-75: FVIKOR performance matrix after normalization for Hospital B

	Patient satisfaction	Health and safety	Reputational image	Sustainability	Creativity and Innovation	Resource and information availability
1a.	[0.26,0.27,0.17]	[0.5,0.64,0.57]	[0.17,0.12,0.03]	[0.21,0.16,0]	[0.2,0.19,0.08]	[0.43,0.5,0.33]
1b.	[0.36,0.42,0.35]	[0.38,0.45,0.34]	[0.22,0.2,0.1]	[0.26,0.25,0.12]	[0.25,0.27,0.18]	[0.27,0.26,0.15]
1c.	[0.26,0.27,0.22]	[0.35,0.35,0.23]	[0.12,0.05,0]	[0.38,0.43,0.35]	[0.16,0.12,0.04]	[0.43,0.5,0.33]
1d.	[0.31,0.34,0.26]	[0.35,0.35,0.23]	[0.22,0.2,0.06]	[0.26,0.25,0.12]	[0.2,0.19,0.14]	[0.48,0.59,0.41]
1e.	[0.31,0.34,0.26]	[0.41,0.45,0.34]	[0.27,0.28,0.13]	[0.26,0.25,0.12]	[0.25,0.27,0.18]	[0.27,0.26,0.15]
2a.	[0.21,0.19,0.13]	[0.23,0.17,0]	[0.22,0.2,0.1]	[0.26,0.25,0.12]	[0.16,0.12,0.04]	[0.32,0.34,0.23]
2b.	[0.48,0.64,0.63]	[0.44,0.54,0.45]	[0.38,0.43,0.28]	[0.26,0.25,0.12]	[0.36,0.49,0.47]	[0.21,0.18,0.08]
2c.	[0.31,0.34,0.26]	[0.29,0.26,0.11]	[0.4,0.51,0.35]	[0.21,0.16,0.07]	[0.3,0.34,0.28]	[0.37,0.42,0.26]
2d.	[0.31,0.34,0.26]	[0.25,0.26,0.11]	[0.43,0.51,0.35]	[0.26,0.25,0.12]	[0.25,0.27,0.18]	[0.21,0.18,0.03]
3a.	[0.26,0.27,0.17]	[0.5,0.64,0.57]	[0.32,0.36,0.21]	[0.26,0.25,0.12]	[0.3,0.34,0.28]	[0.16,0.1,0]
3b.	[0.31,0.34,0.32]	[0.31,0.35,0.23]	[0.32,0.36,0.21]	[0.43,0.52,0.46]	[0.25,0.27,0.24]	[0.27,0.26,0.15]
3c.	[0.33,0.42,0.41]	[0.35,0.35,0.23]	[0.32,0.36,0.21]	[0.38,0.43,0.35]	[0.32,0.42,0.43]	[0.27,0.26,0.11]
3d.	[0.33,0.42,0.41]	[0.38,0.45,0.34]	[0.45,0.59,0.43]	[0.43,0.52,0.46]	[0.32,0.42,0.43]	[0.32,0.34,0.18]
3e.	[0.33,0.42,0.35]	[0.31,0.35,0.23]	[0.32,0.36,0.21]	[0.32,0.34,0.23]	[0.32,0.42,0.37]	[0.32,0.34,0.18]
4a.	[0.46,0.56,0.54]	[0.4,0.54,0.45]	[0.22,0.2,0.1]	[0.26,0.25,0.12]	[0.34,0.42,0.37]	[0.43,0.5,0.33]
4b.	[0.38,0.49,0.44]	[0.38,0.45,0.34]	[0.32,0.36,0.21]	[0.21,0.16,0]	[0.41,0.56,0.57]	[0.37,0.42,0.26]
4c.	[0.33,0.42,0.35]	[0.29,0.26,0.11]	[0.48,0.59,0.43]	[0.21,0.16,0]	[0.41,0.56,0.57]	[0.16,0.1,0]
4d.	[0.36,0.42,0.35]	[0.29,0.26,0.11]	[0.38,0.43,0.28]	[0.26,0.25,0.12]	[0.34,0.42,0.37]	[0.21,0.18,0.08]
4e.	[0.36,0.42,0.35]	[0.31,0.35,0.23]	[0.48,0.59,0.43]	[0.32,0.34,0.23]	[0.34,0.42,0.37]	[0.27,0.26,0.11]
5a.	[0.26,0.27,0.22]	[0.29,0.26,0.11]	[0.27,0.28,0.13]	[0.21,0.16,0]	[0.25,0.27,0.24]	[0.43,0.5,0.33]
5b.	[0.12,0.04,0]	[0.35,0.35,0.23]	[0.27,0.28,0.18]	[0.38,0.43,0.35]	[0.11,0.04,0]	[0.43,0.5,0.33]
5c.	[0.17,0.12,0.04]	[0.35,0.35,0.23]	[0.27,0.28,0.13]	[0.26,0.25,0.12]	[0.2,0.19,0.14]	[0.43,0.5,0.33]
5d.	[0.17,0.12,0.04]	[0.23,0.17,0]	[0.27,0.28,0.13]	[0.21,0.16,0]	[0.16,0.12,0.04]	[0.27,0.26,0.11]
5e	[0.26,0.27,0.17]	[0.5,0.64,0.57]	[0.17,0.12,0.03]	[0.21,0.16,0]	[0.2,0.19,0.08]	[0.43,0.5,0.33]

Table 5-76: FVIKOR indices and alternatives ranking For Hospital B

Alternative	Fuzzy S	Fuzzy R	Fuzzy Q	S	R	Q	Rank
1a.	[1.77,1.88,1.18]	[0.5,0.64,0.57]	[0.75,0.74,0.66]	1.61	0.57	0.72	17
1b.	[1.74,1.85,1.24]	[0.38,0.45,0.35]	[0.47,0.46,0.46]	1.61	0.39	0.46	4
1c.	[1.7,1.72,1.17]	[0.43,0.5,0.35]	[0.56,0.49,0.44]	1.53	0.43	0.5	9
1d.	[1.82,1.92,1.22]	[0.48,0.59,0.41]	[0.73,0.68,0.51]	1.65	0.49	0.64	15
1e.	[1.77,1.85,1.18]	[0.41,0.45,0.34]	[0.55,0.46,0.43]	1.6	0.40	0.48	6
2a.	[1.4,1.27,0.62]	[0.32,0.34,0.23]	[0.16,0.13,0.18]	1.1	0.30	0.16	2
2b.	[2.13,2.53,2.03]	[0.48,0.64,0.63]	[0.9,0.94,0.94]	2.23	0.58	0.93	24
2c.	[1.88,2.03,1.33]	[0.4,0.51,0.35]	[0.59,0.6,0.48]	1.75	0.42	0.56	13
2d.	[1.71,1.81,1.05]	[0.43,0.51,0.35]	[0.57,0.53,0.41]	1.52	0.43	0.5	9
3a.	[1.8,1.96,1.35]	[0.5,0.64,0.57]	[0.77,0.76,0.71]	1.7	0.57	0.75	18
3b.	[1.89,2.1,1.61]	[0.43,0.52,0.46]	[0.66,0.64,0.66]	1.87	0.47	0.65	16
3c.	[1.97,2.24,1.74]	[0.38,0.43,0.43]	[0.6,0.55,0.67]	1.98	0.41	0.61	14
3d.	[2.23,2.74,2.25]	[0.45,0.59,0.46]	[0.89,0.93,0.83]	2.41	0.50	0.88	23
3e.	[1.92,2.23,1.57]	[0.33,0.42,0.37]	[0.46,0.54,0.56]	1.91	0.37	0.52	12
4a.	[2.11,2.47,1.91]	[0.46,0.56,0.54]	[0.85,0.81,0.82]	2.16	0.52	0.83	22
4b.	[2.07,2.44,1.82]	[0.41,0.56,0.57]	[0.72,0.8,0.83]	2.11	0.51	0.78	20
4c.	[1.88,2.09,1.46]	[0.48,0.59,0.57]	[0.77,0.73,0.74]	1.81	0.55	0.75	18
4d.	[1.84,1.96,1.31]	[0.38,0.43,0.37]	[0.53,0.47,0.5]	1.7	0.39	0.5	9
4e.	[2.08,2.38,1.72]	[0.48,0.59,0.43]	[0.88,0.82,0.66]	2.06	0.50	0.79	21
5a.	[1.71,1.74,1.03]	[0.43,0.5,0.33]	[0.57,0.5,0.38]	1.49	0.42	0.48	6
5b.	[1.66,1.64,1.09]	[0.43,0.5,0.35]	[0.54,0.47,0.42]	1.46	0.43	0.48	6
5c.	[1.68,1.69,0.99]	[0.43,0.5,0.33]	[0.55,0.48,0.37]	1.45	0.42	0.47	5
5d.	[1.31,1.11,0.32]	[0.27,0.28,0.13]	[0,0,0]	0.91	0.23	0	1
5e	[1.49,1.38,0.81]	[0.43,0.5,0.33]	[0.45,0.39,0.33]	1.23	0.42	0.39	3

5.8 Concluding remarks

This study introduces a methodology to prioritize improvement projects in the healthcare industry in the context of business excellence models. The proposed approach presents potential factors that can be used to make such decisions in healthcare and provides insight into criteria that is vital to a specific system. The model attempts to increase stakeholder's involvement by incorporating various stakeholders' preferences as well as subject matter experts. Additionally, the model utilizes FIS to rank and select among multiple improvement opportunities in healthcare. The ranking process doesn't only depend on alternatives' expected performance but also on the computed factor weight.

The main advantage of the proposed method is it offers a simple way to gather input from various participants without the need for them to be in the same room. Note that the study attempted to minimize bias by relying on multiple responses for each input in both phases. Also, the approach attempted to mitigate the subjectivity in human judgment by utilizing linguistic terms instead of numbers. Another distinguishing characteristic of the proposed model is the scalability. The model can be executed for any number of improvement opportunities or evaluation factors.

The developed model was tested in the United Arab Emirates with the participation of subject matter experts and related stakeholders. The model dealt with the participants uncertainty through utilizing fuzzy logic. Participants' uncertainty towards a factor is often referred to as a "grey area" of judgment; Fuzzy logic deals with this uncertainty to ensure a qualified analysis outcome. Fuzzy logic was used to merge the participants different opinions to overcome the deficiencies in each and obtain desirable results.

The FDM phase in the model attempted to capture additional factors based on the experts' experience and knowledge in the field. FDM utilization can minimize the group pressure and reduce participants' biases because of the anonymity of the participants. Thus, the study is an example of how FDM can be a suitable method for gathering participants' opinions and finding a consensus while reducing group pressure. Also, it demonstrates that FDM can be a suitable tool for content validation and for gathering additional information that hasn't been explored in the literature.

Post FDM analysis, only eight criteria passed all of the conditions in Hospital A and six criteria in Hospital B. The vital factors for Hospital A include: health and safety, patient satisfaction, reputational image, sustainability, top management commitment, critical to quality, ethical implications, and evidence-based. That represents almost 29% of all of the items on the original list. The factors meeting the conditions for Hospital B are: health and safety, patient satisfaction, reputational image, sustainability, resources and information availability, and creativity and innovation, which represent almost 22% of the total number of items. Common significant factors selected for both cases include health and safety, reputational image, sustainability, and patient satisfaction. Health and safety had the highest importance weight in both cases. The Venn diagrams show that other stakeholders' perceptions bring more critical factors into the evaluation process, which can impact the selection of evaluation factors. The rest of the items failed to achieve the desirable consensus rate; hence they were removed from the list of important factors. More factors could be added if lower values are defined in the comparison conditions. For instance, if the average fuzzy number conditions are manipulated to be greater than 0.55 rather than 0.65, more factors could be retained. Thus, it is important to define conditions that match system objectives and tolerance.

The FIS phase modeling provided insight into each factor's membership function. The interval estimation method was used to model the factor's membership function to model the gray areas between the linguistics class's subset. The variation in experts' responses can be explained by the differences in experts' background, position and years of experience. FIS modeling also clarified the relationship between the inputs and output in each subsystem, the relationship between the subsystems, and the impact of these relationships on the final result. The generated surface plots related the inputs to the output and clarified how to maximize the outputs. For instance, in some cases, altering one input is sufficient to improve the output; however in other cases both inputs must be changed to improve the output, as revealed by the plateau planes in the surface plots.

The final output of the framework is not only a prioritization of the improvements, the subsystem indices shed light on the expected performance of the alternatives from the perspective of each dimension, which can help the healthcare entity to select an improvement that matches their objectives.

CHAPTER 6: CONCLUSION AND FUTURE RESEARCH

6.1 Conclusion

In the modern era, Healthcare providers are encountering growing pressure in the form of rising costs of healthcare delivery, financial constraints, and escalating standards of education and living. Accordingly, the healthcare industry has undergone a profound transformation to improve service efficiency and cope with patients' high expectations. More and more potential improvement projects are being considered in the process of healthcare decision making. In general, the decision of selecting the most effective improvement project from among a wide range is a complex and time-consuming process. The process includes evaluation of different potential projects with respect to various criteria, where some criteria must be given weight according to the organization's objectives. Some of the major obstacles to conducting an effective evaluation are how to define important factors, how to quantify it, and how to get qualitative input from the decision makers, since most of the decision makers prefer using subjective linguistic terms for object rating.

The fuzzy logic approach is a potential technique to overcome those obstacles. Fuzzy logic is a relatively contemporary method that can render human thinking and language in numerical terms and can deals with the 'fuzziness' of human judgment Thus, this research introduces an algorithm for ranking and selecting improvement opportunities in healthcare.

This study sought to develop a framework to prioritize improvement projects in the healthcare industry in the context of business excellence models, seeking to incorporate different stakeholders, in addition to the experts, in the selection process. The rationale behind considering diverse perspectives in decision making is to reduce bias and avoid overestimation or underestimation.

The framework proposed a new approach to rank the improvement opportunities in healthcare by integrating FDM and FIS. The integration of both approaches creates a novel framework that can bridge the gap between decision makers and other stakeholders in healthcare for selecting improvement opportunities. Identifying the evaluation factors that are most important when selecting improvement projects to adopt in a healthcare system is not always straightforward; however, FDM enables systematic identification for potential evaluation factors and allows selection of the most crucial factors for the entity based on passing certain conditions. The modified version of the FDM in this research acquired inputs from different stakeholder groups, including the experts in the field. This modification was intended to enhance stakeholders' engagement in the decision-making process and improve transparency. At the same time, the FIS method was used as a way to overcome the problem of uncertainty and vagueness of preferences in practice while finding the priority index for each alternative. The study utilized HFIS to reduce the number of rules in each subsystem and obtain intermediate values that could represent the indices for each the framework's dimension. Those values assisted in defining the relationship between the main fuzzy system and the subsystems. The HFIS consisted of four layers: an Inputs layer, an Dimensions layer, an Intermediate layer, and an Integration layer. This architecture facilitated defining the layer input and output and constructing the knowledge base for the subsystems within it. The input layer fed the system with expected performance ratings. In the dimensions layer, the subsystems determine the framework's dimensions indexes. The intermediate layer contained the subsystems that aggregated the outputs for each dimension. Finally, the integration layer combined the last two inputs to quantify a priority index.

The analysis in chapter five highlighted some significant topics. First, it proved that the top management still consider the internal stakeholders to be the most important group to participate in the decision-making process. Second, it was proved that healthcare's stakeholders have different perspectives and can bring new insights into the selection process. Third, even in different hospitals, there are still common critical factors between both case studies to assess projects. Those factors are: health and safety, reputational image, sustainability, and patient satisfaction. Health and safety factor ranked as the most important factor. Finally, the FIS phase was found to not only illustrate the priority index, but in fact show the intermediate indices related to the framework' dimensions. Those indices, in addition to the priority index, can aid the organization to select improvement opportunities that maximize a specific dimension.

This study contributes to the body of knowledge by designing a framework to prioritize improvement opportunities in healthcare based on the business excellence model. The study enables the identification of important factors for selecting and evaluating improvement opportunities in healthcare and for validating those factors. Twenty-eight potential evaluation factors and five framework's dimension for improvement opportunities were identified, where each organization could choice from among these factors the most vital according to their objectives. In contrast to the existing model, the developed model includes perspectives from different types of stakeholders in selecting vital factors. Also, it considers the amount of impact that each factor has on the decision-making procedure thorough allocating an importance weight for each factor and including those weights to create a ranking system. In addition, the research successfully integrated FDM and FIS to prioritize improvement opportunities in healthcare based on the business excellence model. Along with calculating the priority index for each improvement, the framework calculates indices for each dimension. Those indices give an insight into the performance of the improvements from the perspective of each dimension. The developed model was tested numerically in two hospitals. The obtained results confirm the feasibility of the framework to assist the decision makers to compare improvement opportunities and select the most valuable based on factors appropriate to their needs.

6.2 Research Limitations

Throughout the study process, several decisions were made to simplify the system to as a result of time and information availability constraints. Although the proposed framework reached its objectives, there were unavoidable limitations. The identification of those limitation poses opportunities for future researches.

First, even though specific criteria were used for selecting the experts, the sampling was still affected by the experts' availability and willingness to participate, especially given that this study required multiple rounds and constant reminders. For example, some experts showed an interest in participating in response to the initial invitation, but they did not respond to the survey in the first round; thus, they were excluded from the study.

There are also limitations associated with the sampling size of the other stakeholders. Regardless of the multiple reminders sent out, the number of doctors and administrators who participated was relatively low in both case studies. Higher numbers could affect the outcomes for each group.

Another major limitation of this study is the availability and the accessibility of some data due to hospitals restrictions. Those data include but not limited to, previous scores in BEMs assessments, the ranking of the BEMs sub-criteria and the opportunities of improvements were identified in the last evaluation.

Also, another limitation is the lack of possibility of validation through comparison. Since no previous study used the same approaches and inability to access the internal hospitals' ranking of the BEMs sub-criteria. Validating the framework through comparison was not an option. Thus, the study is considered an initial study and its result can't be generalized yet.

6.3 Future work

Framework development and implementation raised challenges and further questions, opening the door to the pursuit of plenty of related future efforts. Even though this research can serve as a valuable input for future studies to build on, replicating it in a different healthcare setting or another country would be useful to compare the outcomes and make results more generalizable. This poses as important research opportunity; such a task involves constructing new membership functions and modifying the framework to cope with the characteristics of the healthcare system chosen for study. A comparative study could focus on identifying priority factors in other healthcare settings and test the existence of general patterns or divergence between different countries or healthcare systems.

Also, surveying top management for who to include as stakeholders in the study yielded a selection of only internal stakeholders. Future research could incorporate external stakeholders' perspectives. Patients, for instance, are the end users, and incorporating their inputs might bring additional factors into the study.

A separate research effort could focus on fuzzy rules construction. In this study the fuzzy rules construction was established using the average between two factors; a future modification could allow more systematic fuzzy rule construction. Also, the model assumed an equal importance for all the rules; the study could be modified to assign a different importance to each rule.

Another possible research opportunity is related to the factors' weighting process. The factor weighting in the study relied mainly on a subjective method; however, a comprehensive approach that combines subjective and objective methods to determine factors' weight could enhance the outcome. Also, in total weight calculation, an important weight index for each group could be included rather than assigning equivalent importance for all the stakeholders. This differentiation would represent the impact of each stakeholder in the decision-making process. The effort would focus on defining the importance indices for each group.

Another interesting field of further research is to measure the effectiveness of prioritizing and implementing the improvement initiatives on the overall results of applying BEMs in healthcare organization. Also, utilizing the previous BEM assessment for each sub-criterion as input to the prioritization model, which serve as a feedback loop to the system.

APPENDIX A: EFQM AND MBNQA DETAILED CRITERIA AND SUB-CRITERIA

- EFQM criteria and sub criteria

Enabler	Leadership	1a.	Leaders develop the mission, vision, values and ethics and act as role models
		1b.	Leaders define, monitor, review and drive the improvement of the organization's management system and performance.
		1c.	Leaders engage with customers, partners and representatives of society
		1d.	Leaders reinforce a culture of excellence with the organization's people
		1e.	Leaders ensure that the organization is flexible and manages change effectively
	Policy and strategy	2a.	Strategy is based on understanding the needs and expectations of both stakeholders and the external environment
		2b.	Strategy is based on understanding internal performance and capabilities
		2c.	Strategy and supporting policies are developed, reviewed and updated to ensure economic, societal and ecological sustainability
		2d.	Strategy and supporting policies are communicated and deployed through plans, processes and objectives
	people	3a.	People plans support the organization's strategy
		3b.	People's knowledge and abilities are developed
		3c.	People are aligned, involved and empowered
		3d.	People communicate effectively throughout the organization
		3e.	People are rewarded, recognized and cared for
	Partnerships and resources	4a.	Partners and suppliers are managed for sustainable benefit
		4b.	Finances are managed to secure sustained success
		4c.	Buildings, equipment, materials and natural resources are managed in a sustainable way.
		4d.	Technology is managed to support the delivery of strategy
		4e.	Information and knowledge are managed to support effective decision making and to build the organizational capability
	processes	5a.	Processes are designed, managed to optimize stakeholder value
		5b.	Products and Services are developed to create optimum value for customers
		5c.	Products and Services are effectively promoted and marketed
		5d.	Products and Services are produced, delivered and managed
		5e.	Customer relationships are managed and enhanced
result	People result	6a.	perception measures
		6b.	performance indicators
	Customer result	7a.	perception measures
		7b.	performance indicators
	Society result	8a.	perception measures
		8b.	performance indicators
	Business result	9a.	perception measures
		6b.	performance indicators

- MBNQA category, criteria, and area to address

Category	Criteria Item	Areas to address	Score
1. Leadership	1.1 Senior Leadership	a. Vision, values, and mission b. Communication and organizational performance	70
	1.2 Governance and Societal Responsibilities	a. Organizational governance b. Legal and ethical behavior c. Societal responsibilities	50
2. Strategy	2.1 Strategy Development	a. Strategy development process b. Strategic objectives	45
	2.2 Strategy Implementation	a. Action plan development and deployment	40
3. Customers	3.1 Voice of the Customer	a. Customer Listening b. Determination of customer satisfaction and Engagement	40
	3.2 Customer Engagement	a. Product Offerings and Customer Support b. Customer relationships	45
4.Measurement, Analysis, and Knowledge Management	4.1 Measurement, Analysis, and Improvement of Organizational Performance	a. Performance Measurement b. Performance analysis and review c. Performance improvement	45
	4.2 Knowledge Management, Information, and Information Technology	a. Organizational Knowledge b. Data, Information, and Information Technology	45
5. Workforce	5.1 Workforce Environment	a. Workforce capability and capacity b. Workforce climate	40
	5.2 Workforce Engagement	a. workforce engagement and performance b. Workforce and leader development	45
6. Operations	6.1 Work Processes	a. Product and process design b. Process management c. Innovation	45

	6.2 Operational effectiveness	a. Process efficiency and effectiveness b. Supply-chain management c. Safety and Emergency preparedness	40
7. Results	7.1 Product and Process Results	a. Customer-focused product and service results b. Work process effectiveness results c. Supply-chain management results	120
	7.2 Customer-Focused Results	a. Customer-focused results	80
	7.3 Workforce-Focused Results	a. Workforce-focused results	80
	7.4 Leadership and Governance Results	a. Leadership, governance, and societal responsibility results b. Strategy implementation results	80
	7.5 Financial and Market Results	a. Financial and market results	90

APPENDIX B: UCF IRB APPROVAL

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Determination of Exempt Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **Alia Aldarmaki**

Date: **April 06, 2018**

Dear Researcher:

On 04/06/2018, the IRB reviewed the following activity as human participant research that is exempt from regulation:

Type of Review: Exempt Determination
Project Title: A FRAMEWORK FOR PRIORITIZING OPPORTUNITIES OF IMPROVEMENT IN THE CONTEXT OF BUSINESS EXCELLENCE MODEL IN HEALTHCARE ORGANIZATION
Investigator: Alia Aldarmaki
IRB Number: SBE-18-13749
Funding Agency:
Grant Title:
Research ID: N/A

This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made and there are questions about whether these changes affect the exempt status of the human research, please contact the IRB. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

This letter is signed by:

Signature applied by Gillian Morien on 04/06/2018 02:38:11 PM EDT

Designated Reviewer

APPENDIX C: SEHA APPROVAL

SEHA صحة

Abu Dhabi Health Services Co. شركة أبوظبي للخدمات الصحية

التاريخ: 23 / 11 / 2017

السادة / مدراء التدريب والتطوير الوظيفى المحترمين

المنشآت الصحيه التابعه لشركه "صحه"

تحيه طيبه وبعد ،

<u>الموضوع : تسهيل مهمه بحث طالب</u>

أرجو العلم بأنه تمت الموافقه والسماح للطالبة المذكورة أدناه بأستكمال مهمة بحثها الدراسى فى المنشآت الصحيه التابعه لصحه ، وعليه أرجو التكرم بالتعاون معها لتسهيل المهمة.

- **أسم الطالبة** : عليا حمد راشد رحمه الدرمكي.
- **البرنامج الدراسى** : الدكتوراة فى الهندسة الصناعية والإدارة.
- **الجامعه** : كليه الهندسة وعلوم الكمبيوتر جامعة فلوريدا بالولايات المتحدة الأمريكية.
- **عنوان الدراسه**: وضع إطار لإعطاء الأولوية لفرص التحسين في سباق لموذج تميز الأعمال في الرعاية الصحية.

المطلوب تسهيل إجراءات البحث والتقصى التاليه:

- التواصل بشكل مباشر مع بعض القيادات .
- الحصول على نتائج الأستبيانات السابقه أن وجدت.
- التجاوب من قبل جميع الإدارات مع الأستبيانات والمقابلات المتنوعه الخاصه بالدراسه بهدف قياس النتائج.

وتفضلوا بقبول فائق الأحترام والتقدير ،،

أمل سعيد الجنيبى

مدير التدريب والتطوير الوظيفى بالأنابه

المقر الرئيسى

SEHA صحة
Abu Dhabi Health Services Co. PJSC
(04-1)

www.seha.ae | +971 2 4102311 | +971 2 410 2000 | 109090 | Abu Dhabi, UAE أبوظبي، الإمارات العربية المتحدة

Date: 23/11/2017

To: Managers of Training and Career Development

Health facilities belonging to "SEHA"

<u>Topic: Facilitating Student Research Task</u>

Greetings

Kindly be advised that the below mentioned student has been approved and allowed to complete her research study at the health facilities of SEHA.

Please kindly cooperate with her to facilitate the task.

- **Student's Name**: Alia Hamad Rashied AlDarmaki
- **Course of Study**: PhD in Industrial Engineering and Management.
- **University**: Engineering and Computer Science College, University of Florida, USA.
- **Dissertation Title**: A FRAMEWORK FOR PRIORITIZING OPPORTUNITIES OF IMPROVEMENT IN THE CONTEXT OF A BUSINESS EXCELLENCE MODEL IN A HEALTHCARE ORGANIZATION

The following research and investigation procedures are required:

- Direct communication with some leadership teams.
- Obtaining the results of previous surveys, if any.
- Responsiveness of all departments to various questionnaires and interviews of the study for the purpose of results' measuring.

Yours sincerely

Amal Saeed Al Junaibi

Acting Director of Training and Career Development

Headquarter

APPENDIX D: DUBAI HEALTH AUTHORITY APPROVAL

GOVERNMENT OF DUBAI

UNIVERSITY STUDENT RESEARCH EVALUATION COMMITTEE

هـيئـــة الصـحــة بدبـــي
DUBAI HEALTH AUTHORITY

APPROVAL LETTER

Reference: USREC02-04/PhD/2018 18 Feb 2018

Dear Ms. Alia Aldarmaki,

Title of Project:

"A framework for prioritizing opportunities of improvement in the context of business Excellence model in healthcare organization"

Thank you for your request to conduct research in Dubai Health Authority. Your research Proposal has been reviewed by University Student Research Evaluation Committee, and I am pleased to inform you that your research proposal has been approved to be conducted in Dubai Health Authority.

Please note that the following standard requirements are integral part of the approval:

1. This approval will be for a period of 1 year. At the end of this period, if the project has been completed, abandoned, discontinued or not completed for any reason you are required to inform the University Students Research Evaluation Committee.
2. Please remember that you must notify the Committee via email regarding any alteration to the Project protocol.
3. Please apply for ethical approval through DSREC@dha.gov.ae. After getting your ethical committee approval, you can officially start your research and data assembly.
4. Individuals or organizations conducting research studies in the Dubai Health Authority are expected to provide a copy of the research results to the committee following the completion of the study.

We wish you every success with your studies and beyond.

Yours sincerely

Mahena

Dr. Mahera Abdulrahman, MD, MSc., PhD
Chair, University Students Research Evaluation Committee
Department of Medical Education - Dubai Health Authority
Email: marad@dha.gov.ae

APPENDIX E: ETHIC COMMITTEE APPROVAL

مستشفى العين
AL AIN HOSPITAL

AAH Research Ethics Committee

TO:	Ms. Alia Al Darmaki; alia.aldarmaki@knights.ucf.edu Ph.D. Candidate, University of Central Florida
CC:	AAH Research Ethics Governance Committee
Date:	03rd May 2018
RE:	**Proposed Research Study:** *A framework for prioritizing opportunities of improvement in the context of Business Excellence model in healthcare organization.*
Ref:	*AAHEC-02-18-072*

Dear Ms. Alia,

On behalf of the Al Ain Hospital Research and Ethics Governance Committee, I am pleased to confirm a favorable ethical opinion for the above research on the basis described in the application form and supporting documentation.

The favorable opinion is given provided that you comply as per the context set out in your research study.

You are hereby advised to commence your research study at Al Ain Hospital. In keeping with our policy, the AAH Research and Ethics Governance Committee is kindly requesting you to report any ethical concerns/considerations that may arise during the course of your research, in a timely manner.

Annual Reports plus terminal reports are necessary and the Committee would appreciate receiving copies of abstracts and publications should they arise.

The REC approval is only valid for two years (24 months from the date of the approval letter issued) however it should be renewed yearly for the continuation of the approval. Two (2) months before expiry of the validity period, the Continuing Review Form should be submitted to REC. Late submissions may not be processed in time, and you are not allowed to continue the study without approval.

The Committee is wishing you a success for this project.

Respectfully yours,

Ghanem

Dr. Ghanem Ali Al Hassani
Chairman, AAH Research Ethics Committee
Acting Deputy Chief Medical Officer
Al Ain Hospital

إدارة الشؤون الطبية
مستشفى العين
AL AIN HOSPITAL
CMO OFFICE

P.O. Box 1006, Al Ain
Tel: +971 3 763 5888
Fax: +971 3 763 4322

1.

GOVERNMENT OF DUBAI

DUBAI SCIENTIFIC RESEARCH ETHICS COMMITTEE
APPROVAL LETTER

هيئة الصحة بدبي
DUBAI HEALTH AUTHORITY

From :	Dubai Scientific Research Ethics Committee (DSREC) Dubai Health Authority	**Date :**	20 FEB 2018
To :	Ms. Alia Aldarmaki, PhD student, UNIVERSITY OF CENTRAL FLORIDA	**Ref :**	DSREC-SR-02/2018_02
Study Sites	1) Dubai Hospital, DHA 2) Latifa Hospital, DHA		

Subject: Approval for the research proposal, ***"A framework for prioritizing opportunities of improvement in the context of business Excellence model in healthcare organization"***

Dear Ms. Alia Aldarmaki,

Thank you for submitting the above mentioned research proposal to Dubai Scientific Research Ethics Committee, DHA. The Dubai Scientific Research Ethics Committee has been organized and operates in accordance with the ICH/GCP guidelines and the committee is registered with the Office for Human Research Protection (OHRP).

Your request was discussed with Dubai Scientific Research Ethics Committee. We are pleased to advice you that the committee has granted ethical approval for the above mentioned study to be conducted in Dubai Health Authority. However, you will have to approach the Medical Director of the Hospitals to secure permission to review any hospital records and to carry out your study in the hospital.

Please note that it is DSREC's policy that the principal investigator should report to the committee of the following:

1. Anything which might warrant review of ethical approval of the project in the specified format, including:
    - any serious or unexpected adverse events and
    - unforeseen events that might affect continued ethical acceptability of the project
2. Any proposed changes to the research protocol or to the conduct of research
3. Any new information that may affect adversely the safety of the subjects
4. If the project is discontinued before the expected date of completion (reason to be specified)
5. Annual report to DSREC about the progress of the study
6. A final report of the finding on completion of the study

The approval for the study expires on **20 FEB 2019**. Should you wish to continue the study after this date, please submit an application for renewal together with the Annual Study site progress report no later than 30 days prior to the expiry date.

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حكومة دبي
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هيئة الصحة بدبي
DUBAI HEALTH AUTHORITY

The DSREC wishes you every success in your research.

Yours faithfully,

Dr. Suhail Abdulla Mohd Alrukn
Chairman
Dubai Scientific Research Ethics Committee
Dubai Health Authority

Dubai Scientific Research Ethics Committee
Dubai Health Authority
Dubai, UAE.

APPENDIX F: STAKEHOLDERS' ANALYSIS

<u>Note:</u> Targeted Participant(s): Top Management

Organization name: ____________
Position: __________________
Years of Experience: ________

Dear Mr./Ms.,

Please rate the following stakeholders based on its **Power/Necessity of involvement** when implementing improvement projects in healthcare system (Very Low (VL), Low (L), Moderate (M), High (H), Very High (VH)).

Stakeholder Categories	Code Initial	Power	Necessity of involvement
Patients & Families	P&F		
Local communities	LC		
Commissioning groups	CG		
Insurance companies and other third-party payers	IN		
Other healthcare organizations	HO		
Administrators and managers	A&M		
Doctors/physicians	DR		
Nurses	NR		
Paramedical staff	PA		
Government	GOV		
Authorities	AUT		
Accreditation bodies	ACC		
Evaluation committees	EC		
Observers (future patients, media, etc.)	OBS		
Suppliers	Sup		

APPENDIX G: FUZZY DELPHI SURVEYS

Obtain factor to select improvement projects in a healthcare system
Fuzzy Delphi _Stage 1

<u>Note:</u> Targeted Participant(s): Experts, internal stakeholders, including: physicians, nurses, administration (upon hospital approval)

Organization name: _____________
Position: ___________________
Years of Experience: _________

Dear Mr./Ms.,
The following factor have been listed as those to be considered when selecting an improvement project. Base on your experience in a healthcare system, do you believe any additional criteria should be added? If yes, please add it under the dimension you think it belongs to.

If you agree on the following list as is please check this box ☐

Dimension	Criteria	Description
Operational feasibility dimension (OFD)	Improvement duration/ Time (OFD-C1)	The total time needed to complete an improvement from start to end.
	Resource and information availability (OFD-C2)	The availability of human resources, information, technological capability, and physical assets to support improvement implementation
	Cost (OFD-C3)	The ability of the improvement to fit within the organization's budget, including the operating cost
	Ease of implementation (OFD-C4)	How likely the improvement is to encounter barriers during implementation
Financial impact dimension (FID)	ROI (FID-C1)	The degree to which investment in the improvement can be expected to yield returns and benefits
	Cost reduction (FID C2)	The degree to which the improvement reduces unwarranted expenses to increase profits
	Profit (FID-C3)	The degree to which the improvement generates profit for the organization
Social dimension (SD)	Patient satisfaction (SD-C1)	The degree to which the improvement shows an ability to satisfy patient needs

	Health and safety (SD-C2)	The degree to which the improvement takes into consideration health and safety practices
Strategical dimension (StD)	Urgency (StD-C1)	The need for an immediate action/ improvement
	Impact/effectiveness (StD-C2)	The effect of the improvement on the overall organization's outcomes
	Importance/significance (StD-C3)	The contribution of the improvement to the organization's long-term objectives
	Strategic alignment (StD-C4)	The degree to which the improvement objectives are aligned with the organization's vision and objectives.
	Critical to quality (StD C5)	The degree to which the improvement will upgrade the quality of service
	Competitive advantage (StD-C6)	The degree to which improvement will deliver a unique benefit to the patient
Managerial dimensions (MD)	Top management commitment (MD -C1)	The degree of top management commitment to the improvement
	Learning and growth potential (MD-C2)	To what extent the improvement can improve knowledge and skills
	Risk (MD-C3)	Probability of improvement failure
	Legal implications (MD-C4)	The legal consequences of adopting the improvement
	Ethical implications (MD-C5)	The ethical consequences of adopting the improvement

Additional Comments

Obtain factor to select improvement projects in a healthcare system

Fuzzy Delphi _Stage 2

Which type of these employee 'types' do you most identify with?
☐ Doctors and Physicians
☐ Nurses
☐ Managers and Administration

Gender:
☐ Male ☐ Female

Number of years of experience in health care?

☐ Below 5 ☐ 5-10 ☐ 11-15 ☐ 16-20 ☐ Above 20

What is your age group?

☐ Below 25 ☐ 25-35 ☐ 36-45 ☐ 46-55 ☐ Above 55

Dear Mr./Ms.,
Please rate the following factor based on its **importance** when implementing improvement projects in healthcare system (Very Low (VL), Low (L), Moderate (M), High (H), Very High (VH))

Criteria	Description	Rating
Improvement duration/ Time (OFD-C1)	The total time needed to complete an improvement from start to end.	
Resource and information availability (OFD-C2)	The availability of human resources, information, technological capability, and physical assets to support improvement implementation	
Cost (OFD-C3)	The ability of the improvement to fit within the organization's budget, including the operating cost	
Ease of implementation (OFD-C4)	How likely the improvement is to encounter barriers during implementation	
Regulatory compliance (OFD-C5)	To what extent the improvement meets regulations	
Employee empowering (OFD-C6)	The improvement increases the degree of employee skills and authority	
ROI (FID-C1)	The degree to which the investment in the improvement can be expected to yield returns and benefits	
Cost reduction (FID C2)	The degree to which the selected improvement reduces unwarranted expenses to increase profits	
Profit (FID-C3)	The degree to which the improvement generates profit for the organization	

Patients satisfaction (SD-C1)	The degree to which the improvement shows an ability to satisfy patient needs	
Health and safety (SD-C2)	The degree to which the improvement takes into consideration health and safety practices	
Reputational image (SD-C3)	The influence of the improvement on the organization reputation that perceived by the public	
Urgency (StD-C1)	The need for an immediate action/ improvement	
Impact/effectiveness (StD-C2)	The effect of the improvement on the overall organization's outcomes	
Importance/significance (StD-C3)	The contribution of the improvement to the organization's long-term objectives	
Strategic alignment (StD-C4)	The degree to which the improvement objectives are aligned with the organization's vision and objectives.	
Critical to quality (StD C5)	The degree to which the improvement will upgrade the quality of service	
Competitive advantage (StD-C6)	The degree to which the improvement will deliver a unique benefit to the patient	
Sustainability (StD-C7)	The capability to maintain improvement outcomes	
Replicability (StD-C8)	The ease of duplicating the improvement in another levels	
Evidence-based(StD-C9)	The improvement has an evidence of benefit.	
Creativity and Innovation (StD-C10)	The improvement is creative and has innovative application	
Top management commitment (MD -C1)	The degree of top management commitment to the improvement	
Learning and growth potential (MD-C2)	To what extent the improvement can improve knowledge and skills	
Risk (MD-C3)	Probability of improvement failure	
Conformance to contract or accreditation requirements (MD-C4)	To what extent the improvement meets the requirements of accreditation or contract	
Legal implications (MD-C5)	The legal consequences of adopting the improvement	
Ethical implications (MD-C6)	The ethical consequences of adopting the improvement	

تحديد معايير اختيار مشاريع تطوير نظام الرعاية الصحية

منهجية دلفي الترجيحية_المرحلة الأولى

ملاحظة: المشاركون المستهدفون: الخبراء، أصحاب المصلحة المعنيون من داخل القطاع : الأطباء والممرضون والإداريون (بناءً على موافقة المستشفى).
اسم المستشفى: ____________________
الوظيفة: _________________________
سنوات الخبرة: ____________________

عزيزي المشارك/ـة:
وُضعت قائمة المعايير التالية لتؤخذ بعين الاعتبار عند اختيار مشاريع التطوير. بناءً على خبرتك في نظام الرعاية الصحية، هل ترى أنّ هناك أي معيار يجب إضافته؟ إذا كانت إجابتك نعم، يُرجى إضافته تحت البُعد المناسب من وجهة نظرك.

إذا كنت توافق على ما ورد في هذه القائمة، يُرجى وضع علامة صح في المربع التالي ☐

البّعد	المعايير	الوصف
الجدوى العملية	فترة التطوير/ الزمن	الزمن الكلي اللّازم لإتمام مشروع التطوير من نقطة الصفر حتى النهاية.
	توفّر الموارد والمعلومات	توفّر الموارد البشرية والمعلومات والإمكانيات التكنولوجية والأصول المادية اللازمة لتنفيذ مشروع التطوير.
	التكلفة	تكلفة مشروع التطوير ضمن ميزانية المؤسسة بما في ذلك تكلفة العمليات.
	سهولة التنفيذ	احتمالية مواجهة مصاعب أثناء عملية التنفيذ
الأثر المالي	العائد على الاستثمار	نسبة عوائد الاستثمار في مشروع التطوير
	خفض التكلفة	يخفّض مشروع التطوير المُختار النفقات الغير المبررة لصالح زيادة الأرباح.
	الأرباح	تجني المؤسسة أرباحًا من مشروع التطوير.
البعد الاجتماعي	رضا المرضى	يوفّر مشروع التطوير القدرة على تلبية حاجات المرضى ونيل رضاهم.
	الصحة والسلامة العامّة	مراعاة مشروع التطوير قواعد الصحة والسلامة العامّة.
البعد الاستراتيجي	الضرورة	الحاجة الماسة إلى تنفيذ مشروع التطوير بشكل فوري.
	الأثر/الفعالية	أثر مشروع التطوير على المخرجات الكلية للمؤسسة.
	الأهمية	مساهمة مشروع التطوير في تحقيق الأهداف طويلة الأمد للمؤسسة.
	المواءمة الاستراتيجية	أهداف مشروع التطوير تتواءم مع رؤية المؤسسة و أهدافها.
	الأثر المباشر على الجودة	يعمل مشروع التطوير على تحسين جودة الخدمات.
	ميزة تنافسية	مشروع التطوير يقدم خدمات مميزة للمريض مقارنة بمزودي الخدمات الآخرين

البعد الإداري	إلتزام الإدارة العليا	مدى التزام الإدارة العليا بمشروع التطوير.
	إمكانية التعلّم والنمو	مشروع التطوير يساعد على تحسين مستوى المعرفة والمهارات.
	المخاطر	احتمالية فشل مشروع التطوير.
	التداعيات القانونية	التبعات القانونية المترتبة على مشروع التطوير
	التداعيات الأخلاقية	التبعات الأخلاقية المترتبة على مشروع التطوير

ملاحظات أخرى:

تحديد معايير اختيار مشاريع تطوير نظام الرعاية الصحية
منهجية دلفي الترجيحية_المرحلة الثانية

الهدف من هذه الدراسة هو تحديد المعايير الرئيسية التي يمكن استخدامها لتحديد أولويات التطوير في قطاع الصحة، هذا الاستبيان يهدف إلى تقييم معايير عامة باستخدام تقييمات لفظية مثل: (غير مهم إطلاقا، قليل الأهمية، متوسط الأهمية، مهم، مهم للغاية). ومن المتوقع أن هذه الجولة لن يستغرق أكثر من 10 دقيقة.

في أي وظيفة من التالي تصنف نفسك؟
☐ أطباء ومعالجين
☐ الممرضين
☐ المدراء وموظفين الإدارة

الجنس
☐ ذكر ☐ أنثى

عدد سنوات الخبرة في المجال الصحي؟

☐ أقل من 5 ☐ 5-10 ☐ 11-15 ☐ 16-20 ☐ أكثر من 20

العمر؟

☐ أقل من25 ☐ 25-35 ☐ 36-45 ☐ 46-55 ☐ أكبر من55

عزيزي المشارك/ـة:
الرجاء تقييم المعايير التالية تبعا **لأهميتها** عند اختيار مشاريع التطوير في مجال الرعاية الصحية. (غير مهم بتاتا(VL) ، قليل الأهمية (L)، متوسط الأهمية (M)، مهم (H)، مهم للغاية (VH))

البّعد	**المعايير**	**الوصف**	**التقييم**
الجدوى العملية	فترة التطوير/ الزمن	الزمن الكلي اللّازم لإتمام مشروع التطوير من نقطة الصفر حتى النهاية.	
	توفّر الموارد والمعلومات	توفّر الموارد البشرية والمعلومات والإمكانيات التكنولوجية والأصول المادية اللازمة لتنفيذ مشروع التطوير.	
	التكلفة	تكلفة مشروع التطوير ضمن ميزانية المؤسسة بما في ذلك تكلفة العمليات.	
	سهولة التنفيذ	احتمالية مواجهة مصاعب أثناء عملية التنفيذ	
	الإمتثال التنظيمي	مدى امتثال مشروع التطوير باللوائح والقوانين	
	تمكين الموظفين	يساعد مشروع التطوير على تحسين مهارات الموظفين	
الأثر المالي	العائد على الاستثمار	نسبة عوائد الاستثمار في مشروع التطوير	

البُعد	المعايير	الوصف	التقييم
	خفض التكلفة	يخفّض مشروع التطوير المُختار النفقات الغير المبررة لصالح زيادة الأرباح.	
	الأرباح	تجني المؤسسة أرباحًا من مشروع التطوير.	
البعد الاجتماعي	رضا المرضى	يوفّر مشروع التطوير القدرة على تلبية حاجات المرضى ونيل رضاهم.	
	الصحة والسلامة العامّة	مراعاة مشروع التطوير قواعد الصحة والسلامة العامّة.	
	سمعة المؤسسة	تأثير مشروع التطوير على السمعة العامة للمؤسسة	
البعد الاستراتيجي	الضرورة	الحاجة الماسة إلى تنفيذ مشروع التطوير بشكل فوري.	
	الأثر/الفعالية	أثر مشروع التطوير على المخرجات الكلية للمؤسسة.	
	الأهمية	مساهمة مشروع التطوير في تحقيق الأهداف طويلة الأمد للمؤسسة.	
	المواءمة الاستراتيجية	أهداف مشروع التطوير تتواءم مع رؤية المؤسسة و أهدافها.	
	الأثر المباشر على الجودة	يعمل مشروع التطوير على تحسين جودة الخدمات.	
	ميزة تنافسية	مشروع التطوير يقدم خدمات مميزة للمريض مقارنة بمزودي الخدمات الآخرين	
	الإستدامة	المقدرة على الحفاظ على مخرجات مشروع التطوير	
	القابلية للتكرار	سهولة تكرار مشروع التطوير على المستويات الأخرى	
	الإستناد على الدلائل	مشروع التطوير لدية دلائل فوائد واضحة	
	الإبداع والإبتكار	مشروع التطوير مبتكر وله تطبيقات مبتكرة	
البعد الإداري	إلتزام الإدارة العليا	مدى التزام الإدارة العليا بمشروع التطوير.	
	إمكانية التعلّم والنمو	مشروع التطوير يساعد على تحسين مستوى المعرفة والمهارات.	
	التوافق مع متطلبات العقد أو الاعتماد	مدى مطابقة متطلبات الاعتماد أو العقود	
	المخاطر	احتمالية فشل مشروع التطوير.	
	التداعيات القانونية	التبعات القانونية المترتبة على مشروع التطوير	
	التداعيات الأخلاقية	التبعات الأخلاقية المترتبة على مشروع التطوير	

APPENDIX H: BEM's SUB-CRITERIA RATING

Prioritize improvement projects in healthcare system (Hospital A)

Section one: Definitions

factor	Description
Health and safety	The degree to which the improvement takes into consideration health and safety practices
Reputational image	The influence of the improvement on the organization reputation that perceived by the public
Critical to quality	The degree to which the improvement will upgrade the quality of service
Sustainability	The capability to maintain improvement outcomes
Evidence-based	The improvement has an evidence of benefit.
Top management commitment	The degree of top management commitment to the improvement
Patients satisfaction	The improvement donates an ability to satisfy Patients needs

Section two: Expert Knowledge

Rate the following improvements using (Very Low (VL), Low (L), Moderate (M), High (H), and Very High(VH) subject to each factor

Example: From Health & safety perspective, the expected performance for improvement projects related to (1a. Leaders develop the mission, vision, values and ethics and act as role models) are determined to have (Very Low (VL))

		Reputational image	Health & safety	Evidence based	Patients satisfaction	Ethical implication	Critical to quality	Sustainability	Top management commitment
Leaders	1a. Leaders develop the mission, vision, values and ethics and act as role models								
	1b. Leaders define, monitor, review and drive the improvement of the organization's								

		Reputational image	Health & safety	Evidence based	Patients satisfaction	Ethical implication	Critical to quality	Sustainability	Top management commitment
	management system and performance.								
	1c. Leaders engage with customers, partners and representatives of society								
	1d. Leaders reinforce a culture of excellence with the organization's people								
	1e. Leaders ensure that the organization is flexible and manages change effectively								
Policy and strategy	2a. Strategy is based on understanding the needs and expectations of both stakeholders and the external environment								
	2b. Strategy is based on understanding internal performance and capabilities								
	2c. Strategy and supporting policies are developed, reviewed and updated to ensure economic, societal and ecological sustainability								
	2d. Strategy and supporting policies are communicated and deployed through plans, processes and objectives								
people	3a. People plans support the organization's strategy								
	3b. People's knowledge and abilities are developed								
	3c. People are aligned, involved and empowered								
	3d. People communicate effectively throughout the organization								
	3e. People are rewarded, recognized and cared for								
Partnerships and resources	4a. Partners and suppliers are managed for sustainable benefit								
	4b. Finances are managed to secure sustained success								
	4c. Buildings, equipment, materials and natural resources are managed in a sustainable way.								
	4d. Technology is managed to support the delivery of strategy								
	4e. Information and knowledge are managed to support effective decision making and to build the organizational capability								
processes	5a. Processes are designed, managed to optimize stakeholder value								
	5b. Products and Services are developed to create optimum value for customers								
	5c. Products and Services are effectively promoted and marketed								
	5d. Products and Services are produced, delivered and managed								
	5e. Customer relationships are managed and enhanced								

Prioritize improvement projects in healthcare system (Hospital B)

Section one: Definitions

factor	Description
Resource and information availability	The availability of human resources, information, technological capability, and physical assets to support improvement implementation
Health and safety	The degree to which the improvement takes into consideration health and safety practices
Reputational image	The influence of the improvement on the organization reputation that perceived by the public
Sustainability	The capability to maintain improvement outcomes
Patients satisfaction	The improvement donates an ability to satisfy Patients needs
Creativity and Innovation	The improvement is creative and has innovative application

Section two: Expert Knowledge

Rate the following improvements using (Very Low (VL), Low (L), Moderate (M), High (H), and Very High (VH) subject to each factor.

Example: From Health & safety perspective, the expected performance for improvement projects related to (1a. Leaders develop the mission, vision, values and ethics and act as role models) are determined to have (Very Low (VL))

		Reputational image	Health & safety	Resource availability	Sustainability	Patients satisfaction	Creativity and Innovation
Leadership	1a. Leaders develop the mission, vision, values and ethics and act as role models						
	1b. Leaders define, monitor, review and drive the improvement of the organization's management system and performance.						
	1c. Leaders engage with customers, partners and representatives of society						
	1d. Leaders reinforce a culture of excellence with the organization's people						
	1e. Leaders ensure that the organization is flexible and manages change effectively						
Policy and strategy	2a. Strategy is based on understanding the needs and expectations of both stakeholders and the external environment						
	2b. Strategy is based on understanding internal performance and capabilities						
	2c. Strategy and supporting policies are developed, reviewed and updated to ensure economic, societal and ecological sustainability						
	2d. Strategy and supporting policies are communicated and deployed through plans, processes and objectives						
people	3a. People plans support the organization's strategy						
	3b. People's knowledge and abilities are developed						
	3c. People are aligned, involved and empowered						
	3d. People communicate effectively throughout the organization						
	3e. People are rewarded, recognized and cared for						
Partnerships and resources	4a. Partners and suppliers are managed for sustainable benefit						
	4b. Finances are managed to secure sustained success						
	4c. Buildings, equipment, materials and natural resources are managed in a sustainable way.						
	4d. Technology is managed to support the delivery of strategy						
	4e. Information and knowledge are managed to support effective decision making and to build the organizational capability						
processes	5a. Processes are designed, managed to optimize stakeholder value						
	5b. Products and Services are developed to create optimum value for customers						
	5c. Products and Services are effectively promoted and marketed						
	5d. Products and Services are produced, delivered and managed						
	5e. Customer relationships are managed and enhanced						

APPENDIX I: EXPERT KNOWLEDGE ACQUISITION

Position:
Years of Experience:

Section one: Definitions

Factor	Description
Resource and information availability	The availability of human resources, information, technological capability, and physical assets to support improvement implementation
Health and safety	The degree to which the improvement takes into consideration health and safety practices
Reputational image	The influence of the improvement on the organization reputation that perceived by the public
Innovation and Creativity	The improvement is creative and has innovative application
Ethical implication	The ethical consequence of adopting an improvement
Critical to quality	The degree to which the improvement will upgrade the quality of service
Sustainability	The capability to maintain improvement outcomes
Evidence-based	The improvement has an evidence of benefit.
Top management commitment	The degree of top management commitment to the improvement
Patients satisfaction	The improvement donates an ability to satisfy Patients needs

Section two: Expert Knowledge

From 0 to 100, What are the range numbers for criteria in the first column that describes the subjective levels in the upper raw? For example, the range for "Low" in Improvement duration can be described as (0, 20) whereas "Very high" = (84,100)

Example:

	Very Low		**Low**		**Moderate**		**High**		**Very High**	
	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value
Cost	0	20	20	30	30	70	70	94	94	100

	Very Low		Low		Moderate		High		Very High	
	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value
Resource and information availability	**0**									**100**
Patients satisfaction	**0**									**100**
Health and safety	**0**									**100**
Reputational image	**0**									**100**
Innovation and Creativity	**0**									**100**
Ethical implication	**0**									**100**
Critical to quality	**0**									**100**
Sustainability	**0**									**100**
Evidence based	**0**									**100**
Top management commitment	**0**									**100**
Ethical implication	**0**									**100**

Section two: Expert Knowledge

From 0 to 100, What is the range number of scores for a project that describes the subjective levels in the first column? For example, a project has “Low Moderate Preferred” variable can be described as (30, 40) whereas “Extremely Preferred” = (70, 100).

	(0%=Minimum to 100%= Maximum)	
	Lower Value (%)	Upper Value (%)
Weakly Preferred		
Moderately Preferred		
Strongly Preferred		

APPENDIX J: FUZZY DELPHI METHOD MACROSCODE

```
Sub FuzzyValue()

' data entery sheet variable

Dim EndingRow As Integer ' number of nurses

Dim EndingCol As Integer

EndingRow = 27

EndingCol = 35

i = 2 ' starting clo

j = 21 ' starting Row

Dim x As Integer

Dim y As Integer

x = 6 ' starting row in Expert sheet

y = 3 ' starting col in Expert sheet

Do

    ' put the curser back to the starting rows in both sheets

    j = 21 ' starting Row

    x = 6 ' starting row in Expert sheet

    Do

        ' convert lingustic value to fuzzy value

        If Cells(j, i) = "VL" Then

            Worksheets("Expert").Cells(x, y) = 0

            Worksheets("Expert").Cells(x, y + 1) = 0

            Worksheets("Expert").Cells(x, y + 2) = 0.25


        ElseIf Cells(j, i) = "L" Then
```

```
            Worksheets("Expert").Cells(x, y) = 0
            Worksheets("Expert").Cells(x, y + 1) = 0.25
            Worksheets("Expert").Cells(x, y + 2) = 0.5
        ElseIf Cells(j, i) = "M" Then
            Worksheets("Expert").Cells(x, y) = 0.25
            Worksheets("Expert").Cells(x, y + 1) = 0.5
            Worksheets("Expert").Cells(x, y + 2) = 0.75
        ElseIf Cells(j, i) = "H" Then
            Worksheets("Expert").Cells(x, y) = 0.5
            Worksheets("Expert").Cells(x, y + 1) = 0.75
            Worksheets("Expert").Cells(x, y + 2) = 1
        ElseIf Cells(j, i) = "VH" Then
            Worksheets("Expert").Cells(x, y) = 0.75
            Worksheets("Expert").Cells(x, y + 1) = 1
            Worksheets("Expert").Cells(x, y + 2) = 1
        End If
        x = x + 1
        j = j + 1
    Loop While j <= EndingRow
    i = i + 1
    y = y + 3
 Loop While i < EndingCol
End Sub
```

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